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Vol. 2, No. 5 August 1st, 1947

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OUR COVER

This month we have a radar picture of Wellington and the harbour. The picture was photographed directly from the P.P.I. of the set on the "Port Pirie" as she lay at Glasgow Wharf. Features that may be recognised are the Tinakori Hills, Roseneath heights, and Point Jerningham (Point Halswell is off the picture, since the range to the edge is 3000 yards), Clyde Quay Wharf, the boat harbour, and Mount Victoria. (See story inside.)

CORRESPONDENCE

All correspondence, contributions, and enquiries referring to advertising space and rates should be addressed to:—

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THE SYNCHRODYNE

In a recent issue of an English contemporary, *Electronic Engineering*, there appeared an article describing a new and original type of radio receiver for amplitude modulated waves. The principle on which this receiver operates is by no means new, as it is used extensively in carrier-current telephone communication, but what is distinctly novel is the fact of its application to radio reception.

A new principle of radio reception is hardly likely to create much of a stir in the engineering dovecotes unless it confers some advantages over and above those of systems already in use, but if we were addicted to predictions, which we are not, it would be our guess that much will be heard of the "synchrodyne," as it is called, before very long.

The reason? No more than this: that the synchrodyne principle enables a receiver to have extreme selectivity and as much audio bandwidth as may be desired, simultaneously!

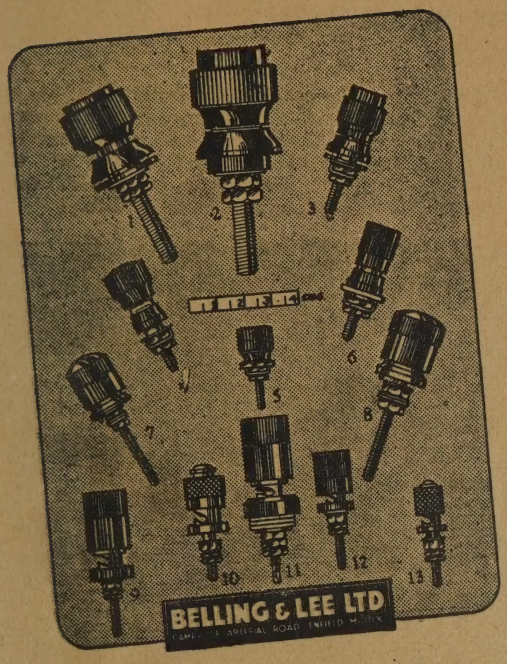
In fact, it appears to be the answer to the ancient problem of attaining high quality reception, together with very good selectivity. At the same time, it appears to open up almost unlimited fields for experiment in communications receiver design.

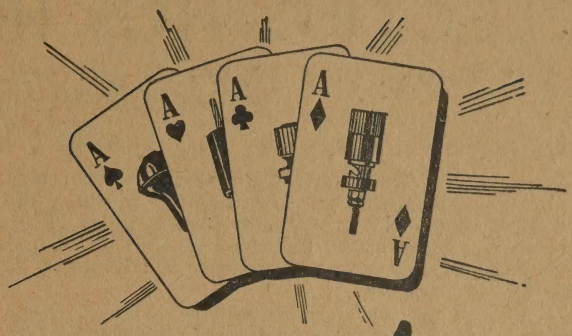
Here, briefly, is how the synchrodyne works. The signals are brought in from the aerial, with or without amplification at radio frequency, and are fed to a local oscillator in such a way that, when the latter is tuned, each signal which is encountered causes it to lock in, exactly on the frequency of the carrier. Now, the modulated signals and the locked oscillator are fed to a demodulator, where the oscillator, of exact carrier frequency, beats with the sideband components of the original signal to produce the audio frequencies as beat notes. Any signal either higher or lower in frequency than the one which is locking the oscillator also produces beat frequencies with the oscillator, but these frequencies are all outside the audio range. Thus, if after the demodulator (or detector) we place a low-pass filter which attenuates strongly all frequencies above, say, 10,000 cycles per second, we have a system in which all frequencies within 10,000 c/sec. of the carrier frequency are passed without discrimination, and yet all frequencies outside the pass-band are attenuated as strongly as we please. Moreover, the degree of attenuation achieved outside the pass band is not dependent on tuned circuits in the pre-detector portion of the receiver. The low-pass filter, in which all the selectivity resides, may just as easily be designed to pass a very narrow band as a wide one, so that selectivity comparable with that of crystal filters may be attained by means of simple filter networks.

Certain features of the synchrodyne may well be termed disadvantages, the chief one being that as the receiver is tuned to a station, a very loud heterodyne whistle is heard until locking occurs, when the heterodyne disappears, and the modulation is heard. In its simplest form, however, the synchrodyne could form the basis of an excellent high-fidelity push-button controlled local receiver, and there is no doubt that many lines of development exist which, if followed up, could almost certainly confer very great advantages on certain types of communications receiver.

However that may be, the synchrodyne is one of the most interesting circuits which has come to our notice for a long time, and we have much pleasure in announcing that our next issue will contain a detailed article on the subject, including practical details of experimental circuits which have been made to function satisfactorily.

Once again the old adage has been proved wrong—there is something new under the sun—and we are grateful to the British Post Office Research Laboratories for inventing it.





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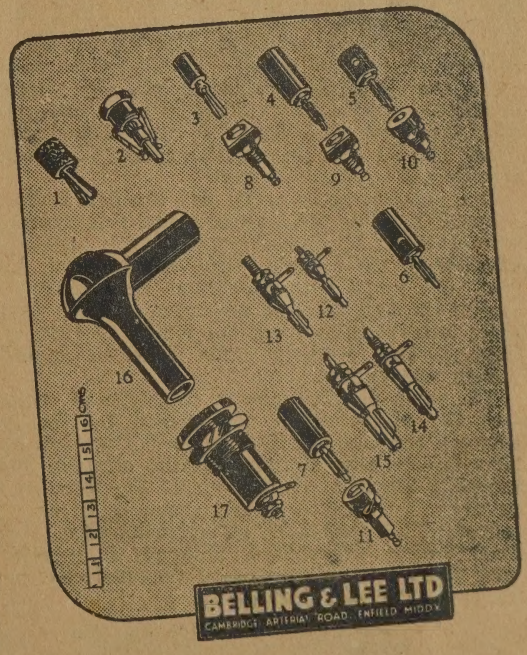


ELECTRONICS IN METEOROLOGY

THE SECOND OF A SERIES OF ARTICLES DESCRIBING ELECTRONIC DEVICES THAT ASSIST THE MODERN METEOROLOGIST

By R. A. EWING, B.Sc.

THE RADIOSONDE

In this article, a fuller description is given of the principle of modern radiosondes, which, as explained previously, are used by meteorologists to obtain observations of pressure, temperature, and humidity in the free atmosphere.

A radiosonde consists essentially of two main parts. In the first place, there are the meteorologically-sensitive elements—one responding to the pressure, another to the temperature, and another to the humidity of the atmosphere. The second part is the radio transmitter, together with the devices for converting the variations in the meteorological components to corresponding variations in the radio transmitter.

The first radiosonde was developed by a Russian scientist, Moltchanoff, just under 20 years ago. In this instrument, the indicating arms of the meteorological elements, which were for pressure and humidity only, passed over a series of contacts as the pressure or temperature encountered decreased. This arm and contact system formed a switch in the plate circuit of a simple radio transmitter, and so a signal was sent every time the arm rested on a contact. Thus it was only necessary to count the number of signals received after the release of the radiosonde to ascertain the position of the indicating arm of the meteorological element. In order to distinguish between the signals sent by the pressure and temperature elements, a further contacting device was placed in series with the primary system. This device consisted of specially-shaped discs attached to a shaft driven by a small windmill. The discs were cut to produce on rotation a signal in the morse code, and when the radiosonde ascended, the signal sent out during the period an arm rested on a main contact took the form of a letter in the morse code, the letter sent by the pressure unit differing from that sent by the temperature unit.

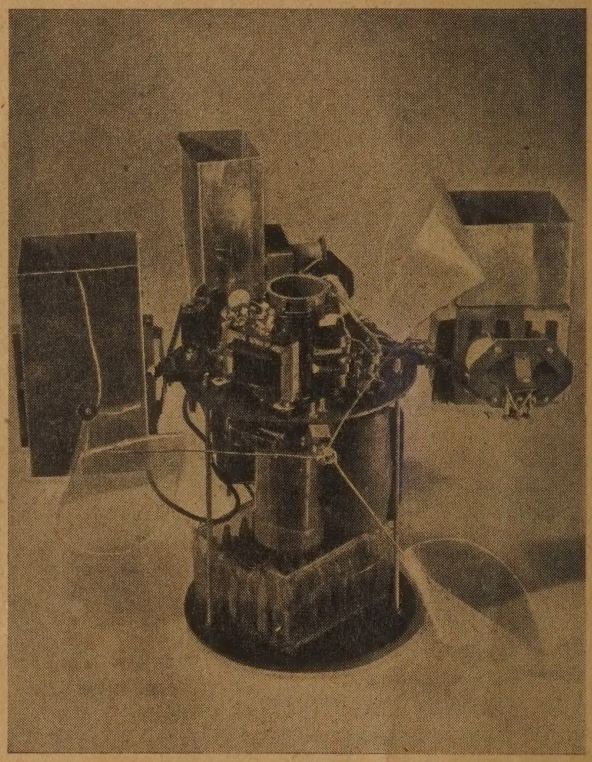
It is interesting to recall that the first radiosondes released in New Zealand were of this type. These were brought to New Zealand by the meteorologist attached to the Lincoln Ellsworth Antarctic Expedition, and when that expedition was delayed for a season through meeting misfortune in the Antarctic, their meteorologist spent the winter of 1934 in New Zealand and released some fourteen radiosondes during that period.

The main disadvantage of this type of radiosonde was the indeterminate lag caused by the friction between the arm and its contacts. This was particularly serious with the temperature element, and also humidity element when used, as the force available to drive the arm of these elements is very small indeed. This principle of operation has therefore been largely superseded, although it is still used with the pressure element of the modern American Diamond-Hinman radiosonde.

MODERN RADIOSONDES

The radiosondes in use to-day employ either one of two principles in the conversion of meteorological measurements into radio signals.

The first is the chronometric principle, where the positions of the arms of the meteorological elements are transmitted as a function of time. The modern Canadian, French, and Indian instruments use this principle, and a fuller description of one of these instruments will be given in a later article.



The British "Kew" Radiosonde, showing the windmill, meteorological elements, and radio transmitter.

The other main principle used in radiosonde is that of causing the meteorological elements to vary the frequency of the radio transmission. A further subdivision of this type is possible, depending on whether the frequency variation occurs in the fundamental radio frequency or as an audio modulation.

The American Diamond-Hinman and the British Kew radiosondes are examples of the modulated audio frequency type, and each will now be described in fuller detail.

AMERICAN DIAMOND-HINMAN RADIOSONDE

In this instrument, the temperature and humidity elements are actually resistances in the grid circuit of the modulating valve of the radio transmitter. The temperature element is a ceramic resistor which has

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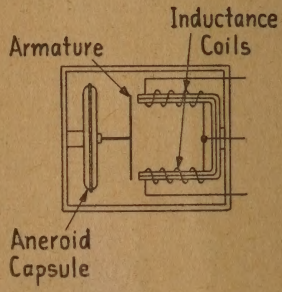
a large negative temperature coefficient. The humidity element consists of a plastic strip coated with an hygroscopic salt, namely, lithium chloride, and the resistance between two metallised edges of this strip varies according to the humidity or wetness of the salt film coating. The pressure element operates as mentioned above in the same manner as the original

starting and stopping of this oscillation gives a measure of the temperature and humidity of the radiosonde.

Radiosondes in flight encounter very low temperatures, often as low as minus 100 degrees Fahrenheit. These low temperatures affect not only the temperature element, but also the other resistors, and to some

Left: The Diamond-Hinman Radiosonde, complete and broken down to show the main components.



Above: Fig. 2.

Below: Component list for Fig. 1.

Moltchanoff radiosonde, namely, by making the arm of the barometer move across a series of contacts. However, this unit, which is known as a "baro-switch," performs another function in that, as well as indicating the pressure, it also serves as a switch to connect into the radio circuit in a definite order the temperature element, humidity element, and also reference resistors.

Only the pressure element is individually calibrated. The temperature and humidity elements have a fixed temperature and humidity-resistance relationship respectively which can be achieved only with an exactitude of manufacture that is warranted when these units are produced in considerable quantity.

The radio transmitter, of which the circuit diagram is given in Fig. 1, employs a twin triode valve. One of these triodes is used as the modulating oscillator, while the other triode acts as the carrier oscillator operating at a frequency of 72.2 megacycles per second. The modulating oscillator is of the "trigger" type, oscillating at the frequency of the tuned circuit formed by the grid coil, L_1, the plate coil, L_2, and the associated condensers, C_1 and C_4. The oscillating frequency is approximately one megacycle per second. The oscillation is intermittent, being controlled by the resistance-capacitance circuit composed by the condenser C_2 and the resistance network formed by R_1, R_8, R_7, the temperature element and the humidity element. Thus the frequency of the

COMPONENT LIST

$R_1 = 40k.$; R_3, $R_6 = 50k.$; R_4, $R_7 = 1000$ ohms; $R_5 = 5k.$; $R_8 = 1$ meg.; C_1, C_4, C_{10}, $C_{12} = 500$ mmfd.; $C_2 = 0.07$ mfd.; $C_3 = 0.05$ mfd.; $C_5 = 0.01$ mfd.; $C_6 = 100$ mmfd.; $C_7 = 250$ mmfd.; C_8 = trimmer; C_{11} = padder; K_1 = S.P.D.T. relay; L_1, L_2 = audio coil; L_3, L_4 = R.F. coil; $V_1(a)$, $V_1(b)$ = 3A5 twin triode.

extent the condensers in the radio circuit, and this produces a drift in both the radio and audio frequencies transmitted.

In the Diamond-Hinman radiosonde, this difficulty is overcome by arranging for the baroswitch to connect fixed resistances into the modulating circuit at regular intervals, and thus a measure of this frequency drift can be obtained.

The ground equipment used with the Diamond-Hinman radiosonde consists of an U.H.F. super-regenerative receiver, the output of which is fed into an electronic frequency meter and recorder, which measures and also records the audio frequency of the received signal.

The electronic frequency meter operates on the principle of the applied voltage (input signal) giving rise to a proportional pulsating direct current, which operates a standard microammeter.

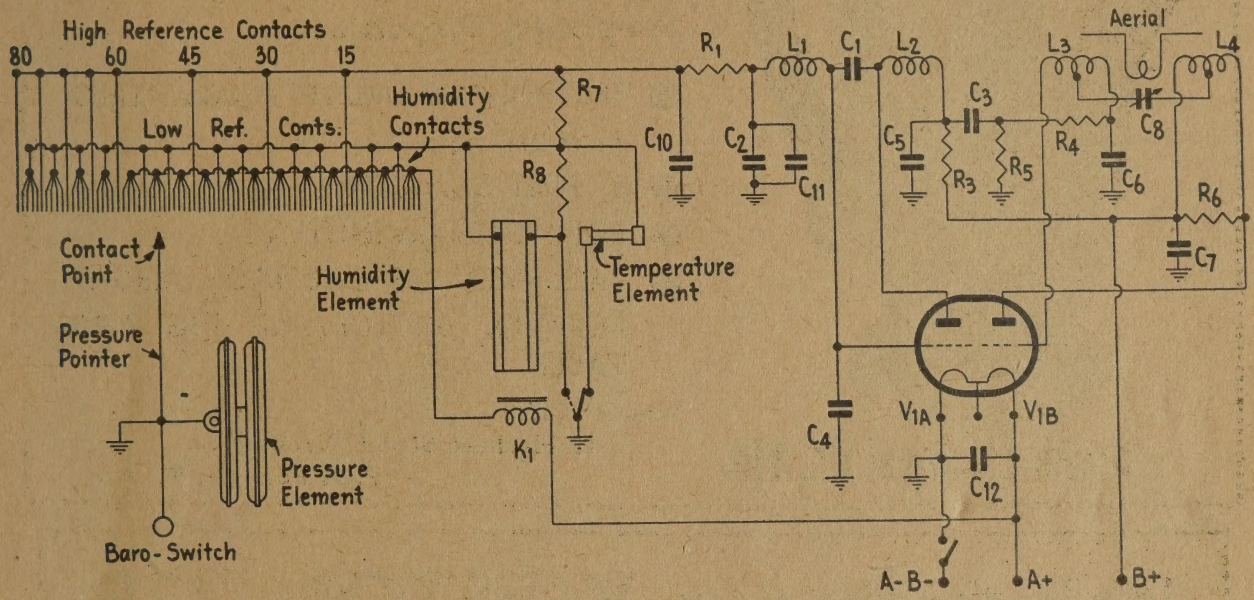
The recorder uses a photo-electric scanning device to cause an impression to be printed on the recorder

chart paper at a point corresponding in value to the position of the microammeter pointer.

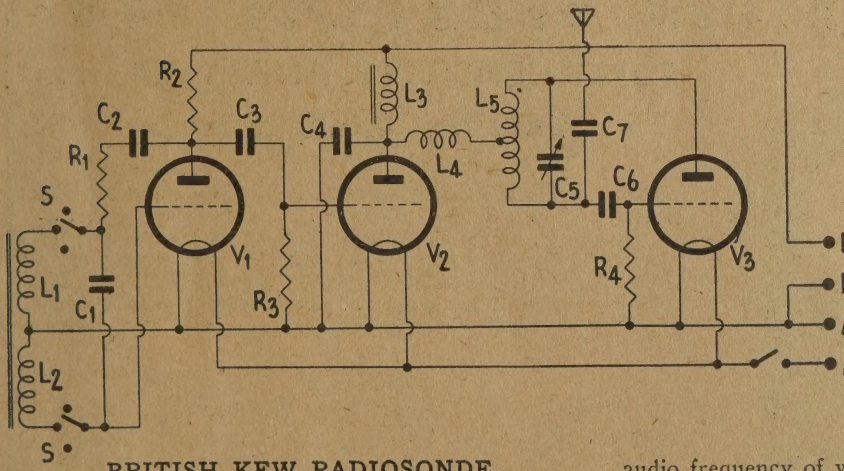
The Diamond-Hinman radiosonde is used by the United States Weather Bureau, Army and Navy, and also by the Australian and New Zealand meteorological services. Regular radiosonde flights commenced in New Zealand early in 1942, when United States Navy aerologists started operations in Auckland with this type of instrument.

beaters" skin for humidity. Goldbeaters skin is obtained from the intestines of a cow, and acts in the same manner as human hair in that it stretches with increasing humidity. Each element, complete with its own inductance, is individually calibrated.

The inductances are switched in turn, by means of a windmill-driven switch, into the audio-modulating circuit of the radio transmitter. Thus the radiosonde emits a series of audio-modulated signals, the



Above: Fig. 1 (for component list see previous page).



Left: Fig. 3. Component list below.

COMPONENT LIST

L_1, L_2=Met. element coil; L_3=A.F. choke; L_4, L_5=R.F. choke; R_1, R_2, R_4=20k.; R_3=50k.; C_1=0.07 mfd.; C_2=0.01 mfd.; C_3=0.001 mfd.; C_4=80 mmfd.; C_5=trimmer; C_6=20 mmfd.; C_7=5 mmfd.; V_1, V_2, V_3=Mazda HL23 (VR130).

BRITISH KEW RADIOSONDE

The Kew radiosonde is the other audio-modulated type of radiosonde that is extensively used to-day.

In this radiosonde, conventional meteorological elements are employed to vary the inductance of an iron-cored winding by mechanically moving an armature towards or away from a U-shaped iron core. Fig. 2 shows how this accomplished in the pressure element.

The meteorological elements for pressure, temperature, and humidity each have their own inductance. These elements consist of an aneroid capsule for pressure, bimetallic strip for pressure, and "gold-

audio frequency of which is controlled by the meteorological elements.

In the Kew radiosonde, a specially-designed three-valve transmitter of high stability towards temperature change is used, and thus the need for employing frequency reference values throughout the flight is avoided. The transmitter, of which the circuit diagram is shown in Fig. 3, operates in the frequency band of 27.5 to 28 megacycles per second.

The Kew ground equipment does not use a frequency meter, but beats the received signal with the output of a tuning fork controlled variable audio

(Continued on p. 48.)

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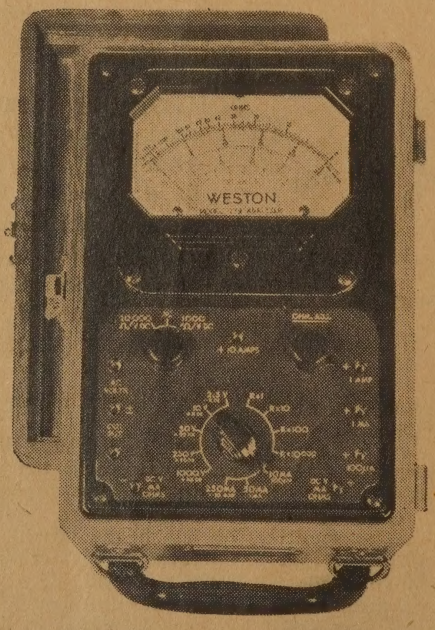

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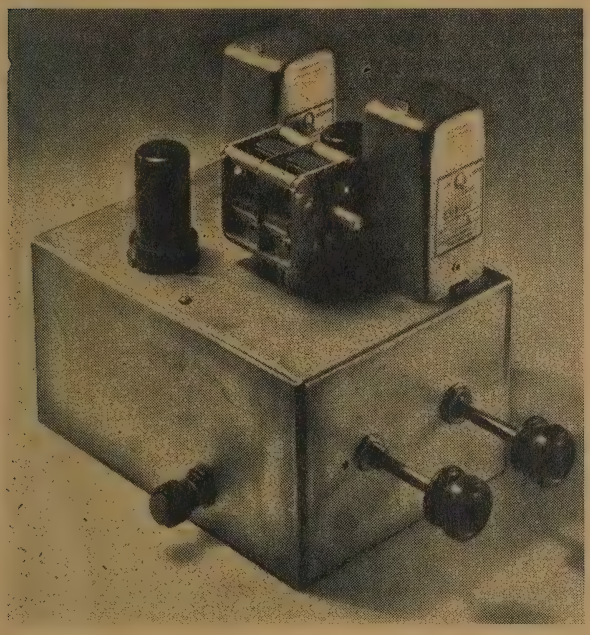
Many a time has the amateur transmitter or DX listener longed for something which would bring weak, barely audible signals up to comfortable listening level, and many times, too, have pre-selectors been constructed, using normal receiving tubes, with the sole result of increasing the noise level equally



General view of the preamplifier. The right-hand control is the wave change switch, and that on the left is the gain control. No dial arrangements are shown, but space is available for fitting any type of movement.

with that of the signal. In such circumstances, a higher overall gain is provided, but no better readability is attained on very small signals. This is the old story of signal-to-noise ratio, which may not be improved in the least if extra R.F. stages are added to a receiver which are more or less identical with the stage already incorporated in the set. Of course, these remarks do not altogether apply to the case of a receiver which does not have an R.F. amplifier stage ahead of the mixer, for this type of set will be improved by the addition of an efficient R.F. stage whatever tube the latter employs. This is because mixer noise is in general much more troublesome than the noise produced by an R.F. amplifier. The point we wish to make here is that if a set has a 6K7 or similar tube in an existing R.F. stage, adding a pre-selector consisting of a further 6K7 will increase the signal-to-noise ratio very little, if at all, with disappointing results.

The idea of using a modern television pentode such as the 6AC7/1852 as an R.F. amplifier in short-wave receivers is by no means a new one, since this type of tube has been recommended for some time as a low-noise high-gain amplifier at high frequencies. However, there are certain difficulties that may be encountered in making the 6AC7 operate satisfactorily in an allwave receiver. Some of these difficulties disappear if the tube is used in a separate R.F. stage, or pre-selector, and now that compact multiband coils in shield cans are available once more, it was considered that the time was ripe for describing a pre-selector that uses a 6AC7, and is quite easy to get going in a stable and worth-while manner.

CIRCUIT FEATURES

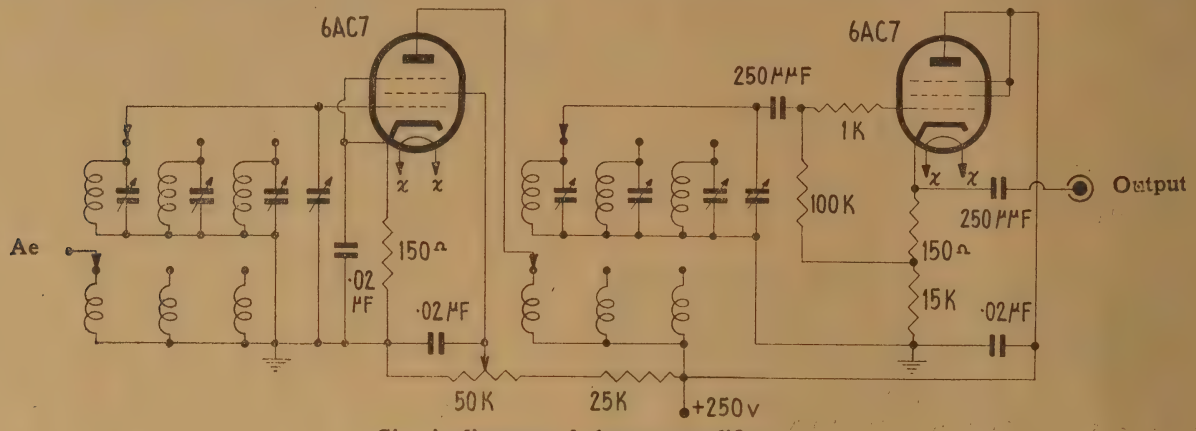
The subject of this article uses two 6AC7's. The first is a conventional R.F. amplifier stage, and the second is used as a cathode follower, which provides increased selectivity and also very efficient coupling between the pre-selector and the aerial terminal of the receiver with which it is to be used. The circuit is simple and straightforward, being a conventional pentode R.F. amplifier circuit, in which the grid circuit is tuned, bias is obtained from a cathode resistor, and gain control is effected by variation of screen potential. Most pre-selectors of this nature have an untuned output circuit in the plate of the R.F. amplifier, and capacity coupling to the aerial terminal of the receiver. The scheme provides very inefficient loading for the amplifier tube and a badly-mismatched coupling to the aerial coil. In the present circuit the use of the cathode follower enables a normal inter-stage R.F. transformer to be used in the plate circuit of the amplifier tube. This in itself gives much more amplification and considerably increased selectivity. At the same time, the low output impedance of the cathode follower ensures that something approaching the full voltage output of the amplifier stage is delivered to the aerial terminal of the set.

It matters very little whether the aerial coil of the receiver is of the low or high impedance variety with this type of connection. For instance, if the aerial coil impedance is high, very little shunting is placed on the output of the cathode follower, so that there is no loss of voltage output. If the aerial coil impedance is low, then it may be as low as 100 ohms or so without reducing the output voltage of the pre-selector by more than a third.

The cathode follower circuit is quite normal and requires no special comment. The 1000-ohm grid stopper, however, should on no account be omitted, or there will be a distinct possibility of regeneration and even oscillation at some frequencies. Any apparent gain increase through regeneration is of

little or no practical value, because it causes a deterioration, if anything, in the signal-to-noise ratio of the pre-selector.

As can be seen in the photographs, the main tuning condensers are ganged, giving single control tuning. Across each coil is connected its individual trimmer, which may be of the ceramic mica compression type, as extreme stability of tuning adjustment is not necessary. For the same reason, a plain dial without any reduction gearing may be used for tuning, as this is not very critical, and a plain movement enables the pre-selector to be tuned rapidly from one end of the band to the other.



Circuit diagram of the pre-amplifier.

COILS AND TUNING CONDENSERS

The coils used in the prototype were the aerial and R.F. coils of the series of triple-wave coils in cans which are on the market. These coils are designed for a 420 mmfd. gang condenser, and suit admirably the midget two-gang condensers that are also held in stock by a number of parts-dealers. The coils are sold separately, and not wired up to a wave-change switch, so that the latter component will have to be purchased as well and wired up by the constructor. However, this is facilitated by the fact that the bases of the coil cans, through which the leads are brought, are clearly numbered, and the manufacturer supplies data sheets giving the numbering code used.

CONSTRUCTION

The method of construction can be quite clearly seen from the photographs. The chassis is in the form of a small box 7 in. x 5 in. x 3½ in. made of 18-gauge steel, cadmium plated. The amplifier tube can be seen mounted between the two coil cans and to the right of the midget gang condenser. Its socket is mounted on a centre 1 in. from the right-hand edge of the chassis and 3 in. from the front. The front edge of the aerial coil can is ⅜ in. from the front of the chassis, which leaves ⅜ in. between this can and the edge of the amplifier socket hole. The R.F. coil can is mounted the same distance behind the valve hole.

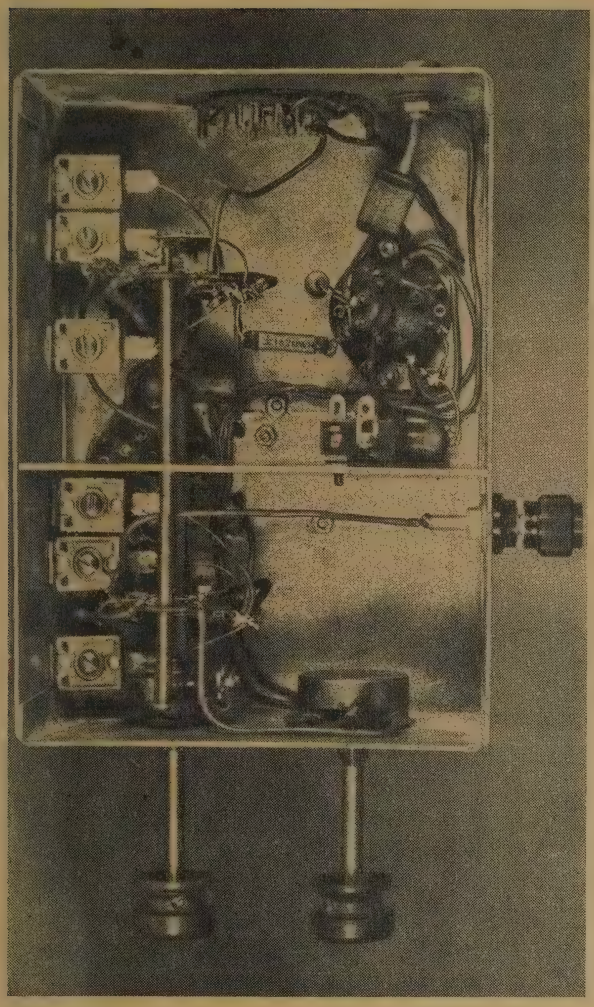
The gang condenser is mounted so that its shaft comes at the centre of the chassis, and its centre shield partition is exactly in line with the centre of the R.F. amplifier tube.

The cathode follower socket is placed on a centre 1¼ in. from the left-hand side of the chassis and 4¾ in. from the front. The terminal to be seen at the left-hand side of the chassis in the top view is the aerial input, while the power input plug and output socket are at the back. The two control knobs in front are, at the left, the gain control, and, on the right, the wave-change switch.

The under-chassis photograph shows the wiring lay-out quite clearly. It is to be noted that an aluminium shield partition has been placed right across the chassis in the exact centre of the R.F. amplifier tube socket. The latter is oriented so that pins 1-4 are in the front compartment and 5-8 in the back one. Thus the shield partition, which has a slot cut in it to accommodate the key of the tube, is taken near enough to the bottom of the chassis almost to make contact with the valve socket, and passes between pins 4 and 5 and 8 and 1. Looking at it from under the chassis, the keyway in the socket faces right, so that the input pins (grid and cathode) fall inside the front compartment and the plate and screen pins in the rear one. This lay-out gives complete shielding between input and output circuits, which is very necessary in view of the high gain of the tube.

The wave-change switch is attached to the baffle-shield. A large hole is bored to accommodate the flat operating shaft, and two smaller ones are provided to take the supporting members. The long washers on the latter are arranged in such a way that the front wafer, which switches aerial and grid coils for the amplifier stage, is about 1½ in. from the front of the chassis, and is therefore immediately above the coil can. The wafer in the back compartment is mounted 2 in. behind the baffle-shield, which places it in line with the second coil can.

All the small components can not be seen in the under-chassis picture, but there are so few of them that their placement does not become a problem. The lead from the moving arm of the gain control potentiometer passes through the baffle-shield via a small cut-out at the right-hand side of the valve socket. It should be noted that the placement of the gang condenser as described above brings the stator leads out one on each side of the baffle-shield, and so should be strictly adhered to. The small two-lug terminal strip on the back of the shield partition



Underneath view, showing layout of trimmers, and the placement of the baffle-shield.

carries the 25,000-ohm dropping resistor which is in series with the gain control. The strip is used as a tie point for one end of this resistor, the other being soldered to the No. 3 pin of the cathode follower socket, which carries the H.T. voltage.

An important point is the shielding of the output lead. To this end a shielded single connection socket is used on the back of the chassis, and the 250 mmfd. output coupling condenser is soldered directly to the centre connection. A piece of braided hook-up wire should be used as the output lead, and can be several feet long, if desired, without introducing undue loss.

ALIGNMENT AND OPERATION

The alignment of the unit is very easily carried out, and does not even require the use of a signal generator, although this is a help. When the wiring has been completed, it is only necessary to connect the pre-selector up to the set with which it is to work. For the heaters, 6.3v. at 0.9 amp. is required, and for the plate supply, 250v. at approximately 20 ma., although the drain will be less when the gain control is not fully advanced. These voltages and currents may easily be obtained from most receivers without straining their power supplies.

Having turned the set and pre-selector on, the alignment is effected by tuning the receiver to about 1400 kc/sec. on the broadcast and turning the gang condenser of the pre-selector so that the vanes are out about 20 degrees from the fully-open end. The broadcast band trimmers are then tuned for maximum noise (or signal) output from the receiver. If the condenser vanes were turned too far in from the open end, it will be found that the trimmers will have to be adjusted to the full-open position to bring the circuits into resonance. The procedure in this case is to unmesh the gang a little, leaving the receiver tuning untouched, and try again. The best adjustment is where the trimmers are screwed about three-quarters of the way down.

An alternative procedure is to place the trimmers in this position initially, and then tune the pre-selector by means of the gang condenser until it comes into resonance at the frequency of the receiver. This done, either the aerial or R.F. trimmer is adjusted for maximum receiver output. If the one first tried is found to give a decrease in output whichever way it is turned, it should be reset to its original position and the other one peaked up.

After the pre-selector has been thus aligned on the high-frequency end of the band, it should be ascertained that the band coverage is correct by tuning to 2YA on the receiver, and then tuning the pre-selector to resonance. If the adjustment of the latter is incorrect, it will not be possible to tune through 2YA with the gang condenser. If this is found to be the case, a greater maximum capacity is required, and the trimmers will both have to be screwed in a little. If this is done, the adjustment should on no account be carried out on the low-frequency end of the band, but at the high-frequency end as before. After the readjustment, the pre-selector is returned to 2YA to make sure that this station is now within the tuning range.

HIGH-FREQUENCY BANDS

The shortwave bands of the coils used have a nominal coverage of 1.7 to 6.25 mc/sec. and 6 to 20 mc/sec. The appropriate alignment frequencies for these bands are 5.5 and 18 mc/sec. respectively. The procedure is exactly the same as described above for the broadcast band, except that in these cases the alignment frequencies may not lie close to the ends of any band on the receiver, which may have entirely different tuning ranges on shortwave. This does not affect the alignment procedure, but it is still necessary to check that the shortwave bands covered by the pre-selector actually do overlap, so that there shall be no gap in the coverage.

USE AND PERFORMANCE

The pre-selector requires no technical knowledge to use, and is therefore very simple to operate. A calibrated dial is unnecessary, as wherever the receiver is tuned, it is only necessary to run the pre-selector tuning quickly over the band to find the right tuning spot. Its selectivity is appreciable, so that, if the receiver dial is moved many degrees, the pre-selector will have to be brought into line with it again before searching for a station is recommenced. However, it is not sufficiently selective

(Concluded on page 48.)

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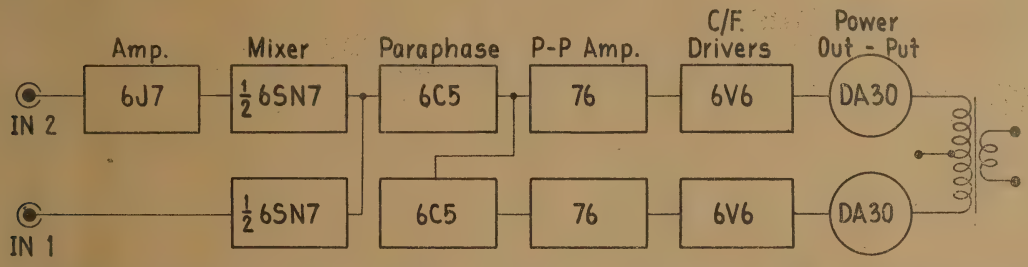
The need sometimes arises for an amplifier with exceptionally good quality, and an output capability of 20 watts or so. Such an amplifier has been built in our laboratory and possesses several novel and interesting features.

The question of obtaining about 20 watts of power at audio frequencies, together with a wide frequency range and very small distortion, is quite a difficult one. No difficulty is encountered if the distortion limit is as high as 5 per cent. total, and if the frequency range is restricted, since class B or class AB amplifiers using receiving type tubes may be made to deliver the power output quite readily under these conditions.

With a 400-volt plate supply, it is capable of an output of 8 watts as a class A single ended power amplifier, so that when used in push-pull, a pair of these tubes can be expected to give substantially more than 16 watts with very high quality. They were chosen for the following reason: There is a notable gap in the standard American series between small power triodes of the 2A3 class and large transmitting tubes like the 845. To obtain 20 watts from



Block Diagram of the Amplifier.

However, when the present amplifier was under consideration, it was decided that nothing but the highest overall quality would suffice, together with good stability of characteristics over a long period. This was sufficient to rule out altogether any possibility of using class AB or B amplifiers. This view is supported by one of America's most noted authorities on audio work, Mr. Hilliard, who has shown conclusively that as soon as one departs from true class A conditions, harmonic and intermodulation distortion starts to increase rapidly. The same worker has also shown experimentally that as long as class A conditions are strictly adhered to, beam-tetrode amplifiers may produce somewhat less distortion than triode amplifiers of the same output rating. The "may" is ours, and refers to the fact that the success of Mr. Hilliard's beam-tetrode amplifiers is due largely to the use of a very special output transformer.

Thus, although his conclusions cannot be challenged on the assumption that this special output transformer is available, it does not follow that the statement holds good when even ordinary high quality output transformers are used.

Other workers, too, while admitting that the best characteristics can be obtained in a beam-tube amplifier, consider that the time-stability of such an amplifier is not nearly as good as that of the triode amplifier. Thus for many purposes where the highest quality is required, triodes are still used. This practice may be amply justified by the fact that the triode amplifier can be relied upon to retain its measured characteristics for long periods, at the same time giving little more distortion than beam tetrodes.

Accordingly the decision was made to accept the very slight increase in distortion, and to use triodes.

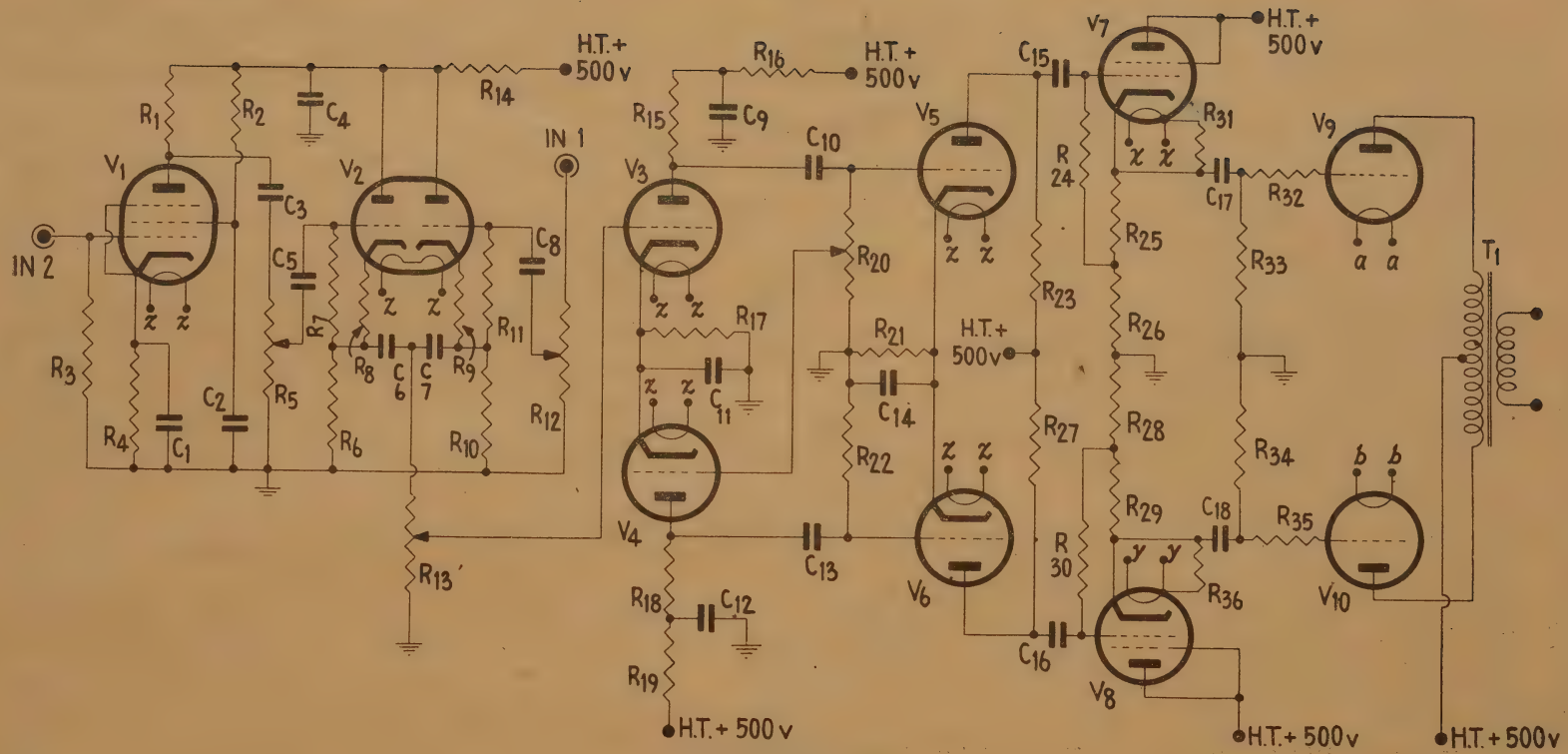
D.A. 30's USED

The tubes chosen for the output stage were of British manufacture—the Osram DA30. This is a large triode with a rated plate dissipation of 30 watts. 2A3's in pure class A at least four of them would be necessary, connected in push-pull-parallel. The necessity for using parallel combinations of tubes is a distinct disadvantage, particularly when high-mutual-conductance tubes are concerned. The use of much larger valves at reduced ratings is definitely uneconomic on account of their high cost. Thus triodes of the size and rating of the DA30 are ideal for the purpose in hand. A non-standard filament voltage, and a slightly increased tube-cost are small prices to pay for the excellent results achieved.

DRIVING CONSIDERATIONS

In this amplifier the DA30's are operated with 400 volts on their plates, and a grid bias of — 102 volts. Since the tubes are self-biased, this calls for an H.T. supply of 500 volts. The driving signal for each tube in the push-pull output stage must be 101 volts peak, and this large voltage must be delivered with virtually no distortion if the amplifier is to have a good overall distortion characteristic. Now this is quite a tall order, and can only be supplied easily by a transformer-coupled driver stage. However, it was not desired to have any more transformers included than were absolutely necessary, both because of the high cost of the best quality transformers, and because of their inferior frequency characteristic—inferior, that is, when compared with a properly designed resistance-coupled system. It was decided, therefore, that resistance coupling must be used throughout the amplifier, the only transformer being the output transformer.

Now DA30's, in common with most power triodes, are recommended to be used with a grid-filament resistance that is quite low. In this case, it is undesirable to have the grid resistor higher than 100,000 ohms, which makes it more difficult than it otherwise might be, to provide the high alternating grid voltage required for full output. An examination of the published resistance-coupled data on American tube



COMPONENT LIST

R_1 = 250k.
R_2, R_3, R_7, R_{11}, R_{24}, R_{30}, R_{31}, R_{36} = 1 meg.
R_4 = 1200 ohms.
R_5, R_{12} = 250k. Pot.
R_6, R_{10}, R_{15}, R_{16}, R_{18}, R_{19} = 50k.
R_8, R_9 = 1500 ohms.
R_{13}, R_{20} = 100k. Pot.
R_{14}, R_{22}, R_{23}, R_{27}, R_{33}, R_{34} = 100k.
R_{25}, R_{29}, R_{32}, R_{35} = 1000 ohms.
R_{26}, R_{28} = 150k.
R_{17} = 1250 ohms.
R_{21} = 3750 ohms.
C_1, C_{11}, C_{14} = 25 mfd. 25v. Electro.
C_2, C_{10}, C_{13}, C_{17}, C_{18} = 0.5 mfd. 600v. paper.
C_3 = 0.004 mfd. 600v.
C_4, C_9, C_{12} = 8 mfd. 450v. Electro.
C_5, C_8, C_{15}, C_{16} = 0.05 mfd. 600v. paper.
C_6, C_7 = 1 mfd. 600v. paper.
V_1 = 6SJ7.
V_2 = 6SN7-GT.
V_3, V_4 = 6C5.
V_5, V_6 = 76.
V_7, V_8 = 6V6.
V_9, V_{10} = DA30.
T_1 = High-fidelity Output Transformer 9000 ohms to voice-coil.

types shows that under given conditions of plate-supply voltage, type 6P5 or its equivalent, the older 76, is the one which produces the greatest output voltage. For example, this tube with a 300-volt plate-supply, a plate load resistor of 100,000 ohms, and a following grid resistor of 0.25 meg., has a rated maximum output voltage of 95v. peak. Under similar conditions, but with a plate supply of 500 volts, the same tube can be expected to give 5/3 of this, or 158 volts peak. However, the following grid resistor must be kept down to 100,000 ohms, which value would cause a large drop in the maximum undistorted output voltage, so that if we were lucky, we might just have enough output voltage to swing the push-pull tubes to maximum output. These conditions are hardly good enough for a very high quality amplifier in which there must be no sign of overloading in the driver stage before the output tubes have reached maximum power output. As was mentioned above, the 76 or 6P5 has a higher output capability than any other resistance-coupled triode, so that a stalemate would appear to have been reached!

CATHODE FOLLOWERS USED

However, there is an answer to every problem, and in this case, as in many others, it turned out to be the cathode-follower. A more striking example of the use of this circuit could hardly be found. First, its low output impedance allows the 100,000-ohm grid resistor of the DA30 to be shunted across it without any observable effect on the available signal voltage; secondly, its input impedance in the present circuit is in the region of 15 megohms. This means that, instead of the 76's plate resistor being shunted by 100k., it is shunted in this circuit by 15 megs., with the happy result that the maximum output voltage of the 76, instead of being 158 volts, as worked out above, is actually raised to 180 volts or so.

At first it was considered that a second pair of 76's would suffice for the push-pull cathode-follower driver stage, but on trial it was found that the available output voltage was only 110 volts peak for each tube. This was considered an insufficient margin of safety, and it was decided that a tube with a higher mutual conductance would have to be used as the cathode follower. The 6V6 seemed a logical choice, and was tried with much better results, the output voltage rising to 140 volts peak before any noticeable deterioration in wave-form was visible on an oscilloscope. Thus the arrangement shown in the block diagram was decided upon.

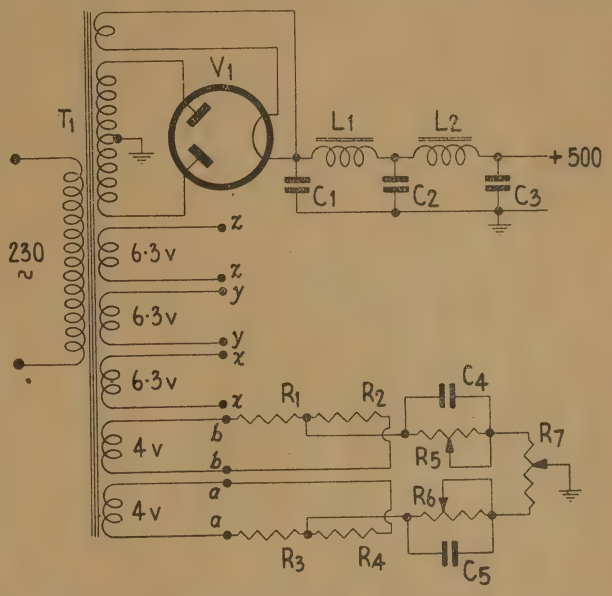
DRIVER FREQUENCY RESPONSE

Since the amplifier was required to be of the highest quality, it was considered essential that the frequency response should be level at least from 20 c/sec. to 20,000 c/sec. This was considered all the more necessary as it is to be used, in our case, not only for the reproduction of music, but as a laboratory instrument by which components and other amplifiers may be judged, and also because there is an output transformer available which has much better characteristics even than this!

Since frequency response was considered so important, the greatest care had to be taken with the design of the interstage coupling circuits, and in particular with the grid circuit of the DA30's. These tubes have an input capacity (including Miller effect) of approximately 60 mmfd., so that for reasons of frequency response alone it was necessary to keep a low value of grid resistor. That the value of 100k. is effective in this respect was shown by taking a response curve for one side of the amplifier, with input applied to one 76 and output taken from the grid of the DA30. This part of the amplifier turned out to have no drop at all at 20 c/sec., and to be 1 db. down at a frequency of 75 kc/sec.!

EARLIER STAGES

The gain of the 76-6V6 arrangement is approximately 10 times, so that for full output a signal of 101/10 or 10.1 volts peak must be delivered to the



Circuit of the power supply. Note that C_4 and C_5, the bias bypass condensers, should have been returned to earth, and not to the ends of R_7 in this diagram.

R_1, R_2, R_3, R_4 = 25 ohm 1 watt.
R_5, R_6 = 1500 ohm 10 watt wire-wound adjustable.
R_7 = 200 ohm wirewound Pot.
C_1 = 4 mfd. 1000v. oil-filled.
C_2, C_3 = 4 mfd. Electro. each made up of two 8 mfd. 450v. Electro. condensers in series, with 1 meg. equalising resistors across each condenser.
C_4, C_5 = 40 mfd. 450v.
T_1 = 500-0-500v. 150 ma., low voltage windings as shown.
L_1, L_2 = 30H. 200 ma. 100 ohms.
V_1 = 5Z3.

grids of the 76 drivers. Since too much gain was not required for the channel labelled Input No. 1, it was decided to use 6C5's in a paraphase circuit ahead of the 76's. Thus the input to the 6C5 grid for full amplifier output is in the vicinity of 10.1/11, or 0.92 volts peak. The performance of the paraphase stage is well within its capabilities. Because of the low output voltage required and the small signal which it handles, its distortion must be very low indeed. This stage, if required to do so, could produce a peak output voltage of 116 under its operating conditions

here. The 6C5's are therefore called upon to produce less than a tenth of their maximum possible output.

THE MIXER AND PRE-AMPLIFIER STAGES

It was considered advisable to provide two input channels for the amplifier, one of which could handle the output of a tuner or gramophone pick-up and the other capable of taking a low-level microphone. In addition, it was desirable to have facilities for mixing the outputs of the two channels and for controlling their respective outputs independently. The cathode-follower audio mixer circuit (presented in "Radio and Electronics" last month) seemed ideal for this purpose, as it gives continuously variable control of each input independently of the other, and irrespective of whether one or both channels are in use simultaneously. The only query here was whether the comparatively high heater-cathode voltage in the mixer stage would give too much 50 c/sec. hum for really high-quality purposes. However, the circuit was tried with excellent results, and was therefore incorporated in the final design.

The 6J7 is used as a pre-amplifier stage with a gain of slightly over 100 times, so that an approximate figure for the maximum signal into channel 2 for full output is 0.01 volt peak, or 0.007v. R.M.S. This is adequate for the average low-level microphone.

Gain controls are provided for each channel, and a third, or main, gain control has been inserted at the output of the mixer stage, or at the input of the amplifier proper. Thus it is possible to arrange for any desired setting of the channel gain controls, while retaining control of the overall level provided at the input of the main amplifier. The response of the pre-amplifier has been purposely restricted at very high and very low frequencies, making it more suitable for the reproduction of speech, where excess high and low frequency response increases the probability of amplifier overload due to extraneous noise. However, no restriction at all has been placed on the frequency response of channel 1, which is as wide as possible.

THE CIRCUIT IN DETAIL

(1) Power Supply and Output Stage

Reference to the power supply circuit diagram shows that the DA30's are individually self-biased. This precaution may be necessary if a pair of unmatched tubes is placed in the amplifier, as the adjustable resistors enable the bias on each to be adjusted until the two tubes draw the same plate current. Since individual bias resistors are used, it is necessary to bypass them for audio frequencies so that current negative feedback may be eliminated.

However, if a pair of tubes is obtained which is well matched, it will be found that the individual plate currents are identical. If this is the case (it was with the pair obtained for our own amplifier), then there is an advantage to be gained by omitting the bypass condensers and joining the centre-taps of the two filament bridging resistors. This places the individual bias resistors in parallel, but retains the use of a separate filament winding for each tube. It also eliminates feedback without the use of bypass condensers, since the output components from the two tubes are out of phase and cancel one another.

Another unusual feature of the power supply is the use of separate heater windings for each of the 6V6 drivers. On account of the high potential at which the cathodes of these tubes reside (300v. positive), it is clearly impossible to use a heater winding which is at earth potential, for fear of heater-cathode breakdown within the tubes. With the separate heater windings, it was found possible to let the heaters "float," without any ill effects, but it was considered better practice to provide a leak from one side of the heater to cathode, so that the heater and cathode could attain the same potential. This also reduces the likelihood of hum arising in this stage. All other heaters are run from the third 6.3v. winding on the power transformer. It would be quite possible, if so desired, to use a separate filament transformer leaving only the rectifier filament winding on the H.T. transformer. This can be done or not according to taste, and will have no effect on performance. The power supply is otherwise quite conventional. Regulation is not particularly important, since the amplifier is operated in class A, and no variation in current drain should occur, except a very slight one on full output. For this reason a condenser-input filter has been used. The chokes have been specified as 200 ma. rating because at least one manufacturer produces a choke answering to the specifications given, which includes a resistance of 100 ohms. This low value is not obtainable in lower-rated chokes, and helps to reduce the required secondary voltage of the H.T. transformer, with consequent reduction in cost.

It will be noted that 1000-ohm grid stoppers have been used in the output stage. This is a necessary

(Continued on p. 37.)

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Included in the unit, but not mounted on the sub-chassis, are the following:—

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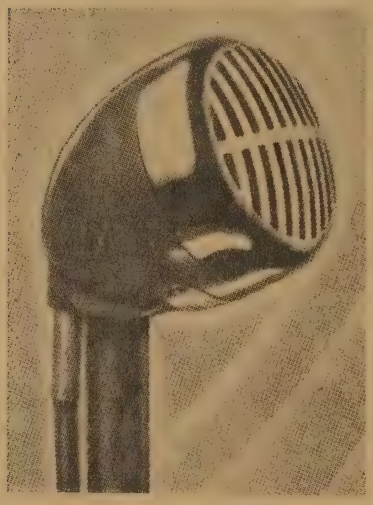
Model	Impedance	Output Level
508B	200-250 ohms	68 db. below 6 milliwatts for 10-bar signal.
508C	High Impedance	60 db. below 1 volt per bar.



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It is finished in irridescent grey finish with highly polished plating on front grille. Natural life-like reproduction. High output level of 53 db. below 1 volt per bar at end of cable. Has a seven-foot single conductor shielded cable with spring protector. The case is a heavy die casting, is simple in design and in excellent taste. Standard ⅝ in.—27 thread. Diameter 2⅜ in. Shipping weight 1¼ lb.

Model	Impedance	Output Level
707A	High Impedance	Output level 53 db. below 1 volt per bar.

SHURE 76B LAPEL CRYSTAL

The Model 76B is designed for public address, lecturing in large halls, broadcasting from portable transmitters, and all general uses where clear, intelligible reproduction of speech is of primary importance and where the user must be able to move freely at all times. It is a pressure actuated diaphragm type crystal microphone especially designed for high quality reproduction of speech when attached to the lapel. The crystal used is a Graphoil (high capacity) Bimorph unit, moisture sealed to withstand climatic conditions. The microphone is inconspicuous, compact and light, weighing only 1½ ozs. It is provided with a 25-foot shielded rubber-jacketed cable. The frequency response of the 76B Microphone extends from 40 to 6000 cycles per second. The high frequency response is especially accentuated for maximum intelligibility and free from undesirable peaks. Only 1⅞ in. diameter. Grey finish. Handy lapel clip, 25-foot shielded single conductor cable. Shipping weight 1 lb. Output level 57 db. below 1 volt per bar.

Model	Impedance	Output Level
76B	High Impedance	57 db. below 1 volt per bar.

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OUR GOSSIP COLUMN

Mr. D. T. CLIFTON LEWIS

This year marks the twenty-first anniversary of genial "Cliff" Lewis's association with Radio (1936) Ltd. We join with his numerous friends throughout the radio trade in offering congratulations upon the completion of a milestone in a career that has been notable for splendid service to the radio industry as a whole.

A New Zealander by birth, Mr. Lewis was educated at Wellington College in J. P. Firth's day. During the Great War he held a commission in the Army. As a young man he was an enthusiastic Scout Master and is still keenly interested in the welfare of the movement. He is one of the few surviving members of that very live pre-war organisation which paid a heavy price in war casualties, namely, the N.Z. Institute of Business Executives; he has followed up this activity by taking a place on the executive of the N.Z. Institute of Industrial Management started by Ron Greenwood of National Carbon. In between business and Masonic interests Mr. Lewis manages to play a little golf.

If it hadn't been for a combination of circumstances—to wit, a cable from America to a group of Auckland business men in 1922 and a barney during the same year between the New Zealand and the Australian Governments, Cliff Lewis might to-day be a big man in the FOOTWEAR trade! For in those days Mr. Lewis was doing very nicely, he'll tell you, with an Australian agency for **boots!** However, it was not to be—importation of Aussie footwear was stopped by the N.Z. Government of the day, and just about the same time Mr. W. A. Boucher (then on tour in the States observing that 'up-and-coming infant broadcasting) was inspired to send a cable to his Auckland associates, which said in effect—"Start a company called Radio Ltd. and put me in for everything." The three gentlemen who acted upon that wire are household names in the trade—W. J. Truscott (Mng. Director of Radio Ltd. and President of the N.Z. Manufacturers' Federation), the late E. T. Boucher and H. V. Coe.

That was in 1922 and in 1926 Mr. Lewis joined the firm as a salesman after a period with A. R. Christian of Ferado fame. In those days Radio Ltd. was assembling 3-valve sets and selling them in a hurry, complete with loud-speakers and batteries, for a mere £85! The word "hurry" was something to ponder in 1926—everybody was saying that saturation point for radio sales was just around the corner!

From salesman, Mr. Lewis moved on to Assistant Manager, and then finally to the Managerial position he occupies to-day. In 1927 he helped form the Radio Trade Group within the framework of the Employers' Association, which made the first successful move in establishing a more satisfactory basis for payment of Royalty fees. He has also assisted in the development of a manufacturers' group through all stages to its present high national status as the Radio Manufacturers' Federation of N.Z. Mr. Lewis is Chairman of the Radio Manufacturers' Association and is a past-president of the Federation. These organisations have undoubtedly given the industry power and prestige—at the present time the Federation is doing good work on behalf of all members in assisting the Government to negotiate a new Royalty agreement with A.R.T.S. & P.

Since its inception Mr. Lewis has been Chairman of the Radio Industrial Planning Committee, which was gazetted early in the war.

Many will recall that dismaying period when the whole New Zealand radio trade was practically at a standstill following declaration of hostilities and before the war potentialities of the New Zealand radio industry were properly realised by the authorities. It speaks volumes for the vision and confidence of the leaders of the radio trade that they persevered for full utilisation of the radio trade's resources against a sceptical Army authority. Their greatest success, represented by the completion of the ZC1 contract on behalf of the Eastern Supply Commission—one of the biggest single jobs ever handled by any manufacturing industry in New Zealand—is too complex and broad to be dealt with in the scope of this personal article. We will do so in detail later. Meantime we are glad to record an appreciation of Mr. Lewis's initiative in this great project, although he naturally and rightly maintains that all credit belongs to the appointed war-time controller, Mr. Ralph Slade.

In 21 years with Radio Ltd. Mr. Lewis has seen over 100,000 radio sets pass out of the factory. During the war they made highly secret testing gear for the Navy, carried out wiring for Radar, made tripods for compasses, built trench mortars and other paraphenalia of war. Now they have added electric kettles, irons and other household appliances as well as inter-communication systems to their list of products.

Truly a formidable and varied list of engineering and electrical products has been encompassed by the ex-footwear salesman, who to-day enjoys a reputation in the industry equalled only by the best of its technical men. In June Mr. Clifton Lewis went on a holiday trip to Suva and with him went the good wishes of all radio people for an enjoyable rest from his labours.

TRADE WINDS

GREEN AND COOPER INSTALL LARGE RADIO SYSTEM

Green and Cooper, Ltd., of Wellington, through their New Plymouth agents, Messrs. Hughsons Ltd., have obtained the contract for the new radio installation at the New Plymouth Hospital.

The three-channel system embodies very modern facilities which allow the patient the choice of three programmes. Approximately 180 beds are being wired and provision is made for the use of a microphone and records.

Four speaker amplifier points are being installed in the ward sitting-rooms. The complete system incorporates noise-suppression and special tone compensation to overcome line difficulties. The equipment is built into a 6 ft. rack, and the panels are standard 19 in. width.

(Continued on p. 48.)

TONIGHT—

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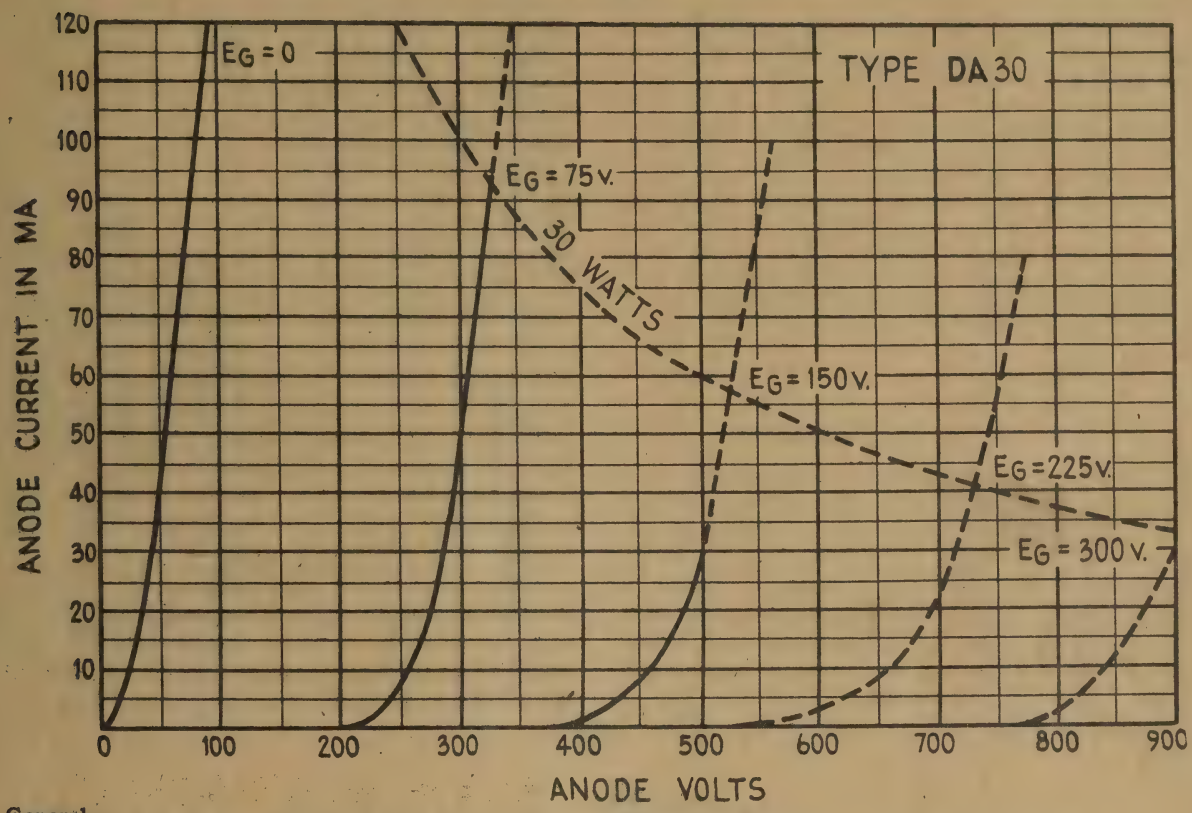
TUBE DATA: *The DA30 Power Amplifier Triode*



General

This tube is very litle known in this country, being of British manufacture. It fills a long-felt gap in the American power triode series of tubes, and is excellent for class A or AB1 applications, where, if American types were used, four 2A3's in push-pull parallel would be necessary. It is an Osram valve, manufactured by the General Electric Company of England. In this issue will be found an amplifier designed round this tube, and capable of very high quality at an output level of 20 watts or so. At maximum ratings a pair of DA30's is capable of 45 watts output in class AB1. Class AB2 operation is not possible with this type.

CHARACTERISTICS

Filament voltage	4.0v.
Filament current	2.0 amps.

Note.—The voltage measured at the socket should not be less than 3.9 volts, or else trouble may be experienced from emission saturation.

INTER-ELECTRODE CAPACITIES

Grid to plate	13 mmfd.
Plate to filament	6.5 mmfd.
Grid to filament	10.0 mmfd.

Valve Constants

Measured at a plate voltage of 500, and plate current of 60 ma.:—

Amplification factor	2.8
Mutual conductance	3.7 ma./v.
Plate resistance	760 ohms

Maximum Ratings

Maximum plate voltage	500v.
Maximum plate dissipation	30 watts

TYPICAL OPERATION

(1) Single Valve, Class A		
Plate voltage	500	400v.
Grid bias	—134	—102v.
Cathode bias resistor	2233	1633 ohms
Plate current	60	62.5 ma.
Load impedance	6000	4500 ohms
Power output	11	8 watts
(2) Push-pull, Class A (self bias)		
Plate voltage	500	400v.
Grid bias	—134	—102v.
Plate current (no signal)	120	125 ma.
Load impedance (P-P)	12,000	9000 ohms
Common cathode bias resistor	1116	816 ohms
Power output	22	16 watts

Note.—The stated values of power output are at very low second harmonic distortion level. Figures for 5 per cent. second harmonic will be in the region of 28 and 20 watts respectively.

(3) Push-pull, Class AB1 (fixed bias)		
Plate voltage	500	440v.
Grid bias	—145	—117v.
Plate current (total)	50	57 ma.
Load resistance (P-P)	3400	2800 ohms
Power output	45	32 watts

Note.—When being used at full output under class AB1 conditions, it is advisable to connect a diode from each grid to earth, to ensure that the grids can never reach a positive potential. A 6H6 or similar tube may be used, with the cathode earthed and one plate directly connected to each grid.

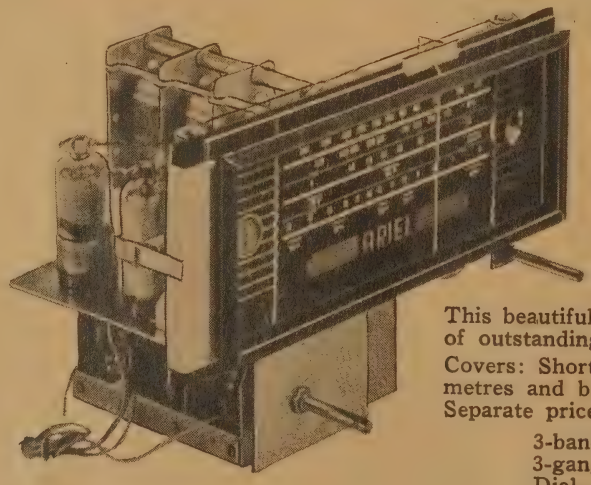
Also grid-stoppers, 1000 ohms each, are strongly recommended when a pair of DA30's are operated in push-pull, either class A or class AB1.

Characteristic Curves

A family of plate characteristic curves is given for the DA30. On the curves is drawn a dotted line showing the region in which the static operating point may lie without exceeding the rated plate dissipation of 30 watts. Points above this line represent excessive plate dissipation.

SEEN IN AUCKLAND

A peace-time application of the electronic mine-detecting technique was to be observed in the streets of Auckland recently. The gentleman with the head-phones and portable loop is uncovering some of the mysteries of the town's underground works by means of an instrument working on the same principle as the war-time article with which some of our readers no doubt have more than a nodding acquaintance.



3 Valve Tuner Assembly

Complete with R/F and Mixer Valve **£10**

This beautifully built job has been air-tested and proven capable of outstanding performance.

Covers: Short-wave band—16/49 metres; Amateur band—49/140 metres and broadcast. Completely wired and calibrated. 9 coils. Separate prices for component parts as follows:—

3-band Tuner Unit	£4/17/6
3-gang Condenser	17/6
Dial	£2/12/6

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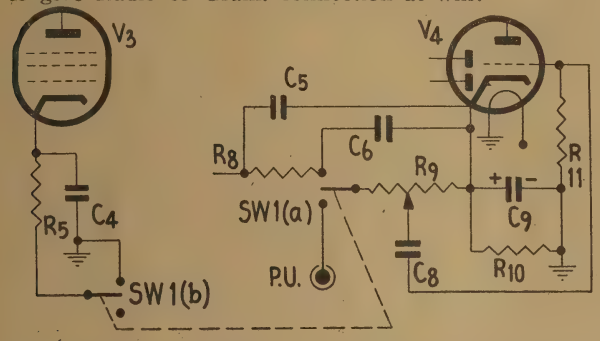
OUR BEST SELLER!
Portable Radio Kit
5 Valve with R/F stage

Absolutely complete, including cabinet, batteries, etc. **£14 17 6**

QUESTIONS AND ANSWERS

A.E.B., Christchurch, writes:—"I have just built up a receiver using the Bandspread Six tuner in conjunction with the push-pull 6V6 amplifier described in the December, 1946, issue of 'Radio and Electronics.' I wish to connect it up as a radio-gramophone combination and would like to know if you can help me with the pick-up connections. When I take off the grid-clip of the 6Q7 and connect the wire from the pick-up to the grid (the other pick-up wire to chassis) I get sufficient hum to spoil the reproduction, which is excellent on the 'Radio' position. Would there be enough amplification if the pick-up were connected after the 6Q7 stage, and would it be possible to install a change-over switch to give Radio or Gram. connection at will?"



Showing how a Radio/Gram. switch may be added to a 6Q7 second-detector cum first audio tube where the diode load R_9 is also used as the volume control.

In the first place, the gain of the 6Q7 is necessary, so that the grid circuit of this tube is the place to which the pick-up should be connected.

The accompanying circuit diagram shows how the change-over switch may be wired up. In the diagram the code numbers refer to the lettering of the original Bandspread Six circuit, but the arrangement shown can be used for any double-diode-triode circuit such as this, where the diode load resistor is also the volume control. It will be noted that a double-pole switch is used, the second section making the I.F. amplifier stage inoperative on the "Gram." position by opening its cathode circuit. This precaution is necessary in order to prevent the feeding through of radio signals in this position of the switch. It enables an ordinary high-capacity rotary or toggle switch to be used without danger of feed-through.

The hum you have encountered may be due to improperly shielded pick-up leads. It is important to see that the output lead of the pick-up is properly shielded, and that the shield braid is connected to the chassis. It is sometimes advisable to use two wires instead of one, inside the shield braid, one wire being connected to the latter at the output end only, and used for the "low" side pick-up connection to the chassis.

C.P.F., Wellington, writes:—"I should like to make a suggestion which I think would improve the present method of presenting schematic circuit data, from the reader's point of view. It is this: that instead of listing circuit values in panels below the diagram, this information should be inserted adjacent to the components in place of the C and R code numbers.

"This would greatly facilitate the study and appreciation of such a receiver as the 'DX Broadcast 12,' for in its existing form considerable time is lost in searching for circuit values not in numerical sequence, in the panels.

"I realise that this may present some little difficulty in certain cases, but trust you will find the suggestion worthy of consideration.

"In conclusion may I compliment you on the excellent standard both in production and technically, which you have maintained in your publication."

First of all we have to thank C.P.F. for his suggestion, which touches a subject which has given us much food for thought.

While we agree that it would be an advantage to the reader in some ways to have all circuit values indicated directly on the diagram, there are compensating disadvantages in many cases, which would entirely outweigh the advantages, to our way of thinking.

In the first place, when a circuit requires considerable description, as for example the "Broadcast 12," or the "Service Oscilloscope" published in our early issues, the absence of code numbers would make the article very difficult to read, if not actually annoying. The point is that if no code numbers are used, it is necessary to use cumbersome circumlocations in order to specify a particular resistor or condenser. It is not too much to say that complex circuits cannot be adequately described at all if code numbers are not used.

Of course, one way out of the difficulty would be to put both values and numbers on the circuit diagrams, but this brings up the other main point involved—that of space. Were the direct lettering system used on circuits containing many valves, the circuit would have to be drawn much more "loosely" in order to find room for the values, which in most cases take up much more space than the code numbers. This would mean that in order to get these multi-valve diagrams on the page, it would be necessary to reproduce them to a much smaller scale, which would again react unfavourably on the reader's ease of interpretation.

Readers will probably have noticed that in a number of cases where the description is small in extent, we have already used the direct lettering system. No doubt the system could be used a little more frequently than it is at present, and we will be glad to give further consideration to each case as it occurs.

We have little doubt ourselves, however, that the code number system is the most satisfactory one from most points of view, but we would be glad to hear from other readers who may wish to express an opinion on this subject.

Finally, we would like to thank C.P.F. for his complimentary remarks, and we hope that we will be able to carry on with the good work to everyone's satisfaction.

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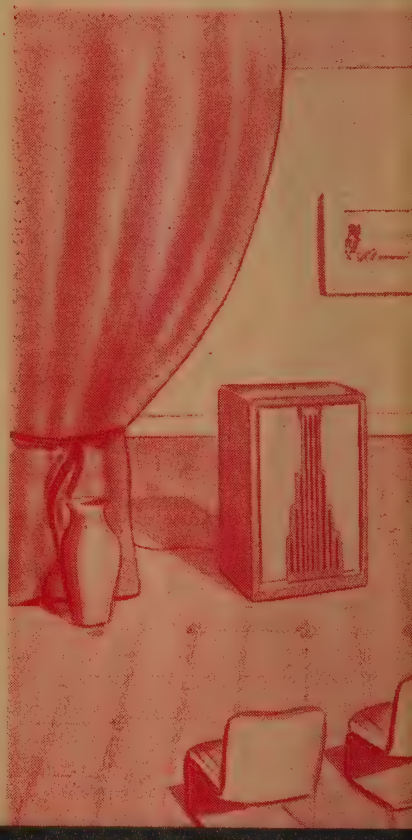
This Speaker Baffle is designed to give the highest quality reproduction using a P.M. speaker. The cabinet is finished in a polished walnut veneer of rich texture and is available with either a 10 in. or a 12 in. Heavy Duty P.M. Speaker Unit.

Dimensions: Height, 36 in.
Width, 25 in.
Depth, 15 in.

Power-handling Capacity:
Type BR10 10 watts.
Type BR12 15 watts.

Six standard impedances are available from 2.7 to 7000 ohms. Other impedances can be supplied if necessary.

Prices on application.



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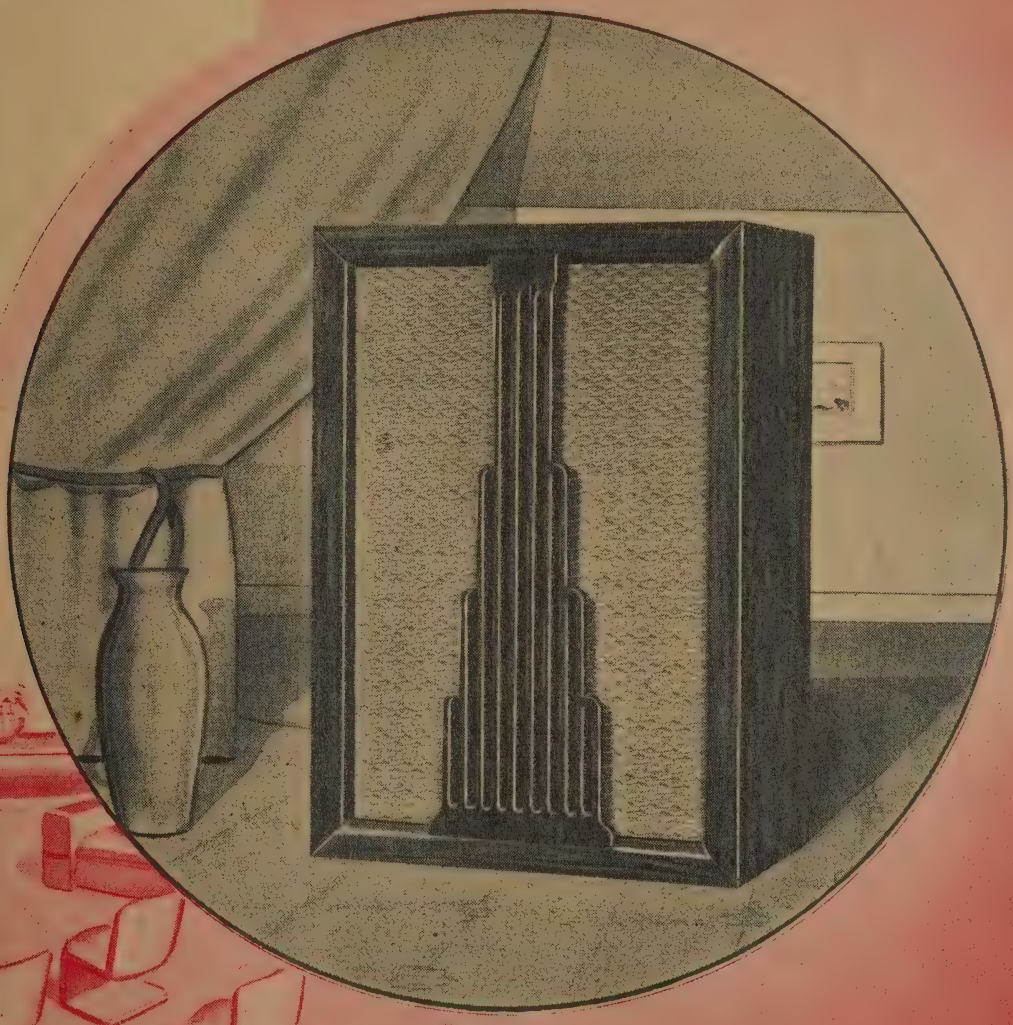

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The Service Section—Practical Trouble-Shooting

By C. R. LESLIE, late Technical Officer, Royal Aircraft Establishment.

PART 6—RECEIVER FAULTS

I. HUM

In the early days a low mains hum was fairly general, but with the advance in design and improvement in component construction this background annoyance has been almost entirely eliminated. At the present time a noticeable hum indicates something amiss and the necessity for urgent expert attention. Although a proportion of the listening public are appreciative of this, there is still a large number who leave matters till the interference becomes too bad for entertainment value, or worse still, till the receiver throws in the sponge, and then considerable mischief is likely to have been wrought in the "innards" with correspondingly high repair bills.

Hum can arise from various causes and may be classed in three groups:—(1) Straight-out mains hum due to a breakdown in the smoothing system in A.C. and A.C./D.C. sets; (2) picked up and amplified hum, which can occur in any type of receiver; and (3) modulation hum. In effect, the first two are much alike and must be differentiated by test, while the third occurs only when a signal is tuned in. This last cannot necessarily be sorted out by tuning to transmissions as it may be present together with hum from the other two groups. For the purpose of discussion we will assume a defective receiver and consider various methods of localising the trouble.

The first and most obvious step is to inspect the smoothing electrolytics for outward signs of deterioration, such as the bulging of cases, oily spots on cardboard containers or extrusion of the electrolyte or white paste. If the appearance looks normal we can check them by substitution of a hook up of new components **after isolating the existing ones**, or we can make leakage tests by inserting a milliammeter in series with each in turn as mentioned in Part 2 of this series. If there is no detectable leak it may be assumed that the electrolyte has dried up and hence the condenser is providing no capacity and therefore no smoothing action.

If the electrolytics are in order we can check the output stage by shorting the grid circuit (or grid circuits in push-pull) of the output stage. If hum persists, disconnect the output transformer primary and join together the leads ordinarily connected to it so as to supply H.T. to the valve anode to maintain a normal load on the mains transformer. Across the primary of the output transformer connect a resistance equal to the valve impedance (which is **not** the optimum load value) so that the transformer will be correctly loaded. Switch on and allow to warm up and if hum continues it can only be due to the speaker field. Nowadays energised speakers are fitted with a "hum bucking" coil in series with the speech coil, and the field is used as a smoothing choke. Shorting of the hum bucking coil is not likely but it is a possibility. The most likely cause of hum now (assuming the electrolytics are in order) is excessive ripple from the rectifier valve due to uneven plate emission. A substitution may cure this, but if not we must check the A.C. voltages of the two halves of the H.T. secondary of the mains transformer, as different voltages will have a similar effect.

If hum ceases when the output transformer is disconnected as above but reappears on re-connection, then there must be some fault in the valve circuit, either in the plate or screen grid circuits, the cathode

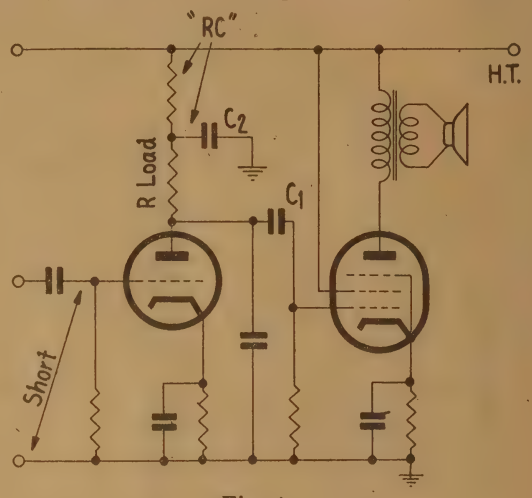

Fig. 1.

biasing or filament supply. Hum is only likely in the filament supply of directly heated valves if the "centre tap" of the L.T. secondary of the mains transformer is appreciably off centre. This may be remedied by connecting a 50-ohm "pot." across the secondary with the slider earthed and the centre tap disconnected. The cathode by-pass electrolytic can be conveniently checked by substitution. Hum from the anode or screen grid circuits will be due to inadequate smoothing, the remedy for which is either to increase the capacity of the smoothing electrolytics consisting of a smoothing choke and condenser or add an extra section to the smoothing filter, between the rectifier and the speaker field.

With the output stage cleaned up, short the grid circuit of the preceding L.F. amplifier valve and if hum ceases but recommences on removing the short then it must be coming from a still earlier stage. Assuming, however, that hum persists with the grid shorted it must obviously emanate from this stage. (See Fig. 1.) First disconnect the coupling condenser C_1 and if this cures the trouble then it must be due to a faulty valve, bias supplies or defective decoupling condenser C_2. On the other hand if hum continues with C_1 out of action it must be due to electrostatic pick-up in the grid circuit of the OUTPUT valve. Try reducing the value of the grid leak and increasing the capacity of C_1, to maintain the C.R. constant, or alternatively substitute earthed screened wiring to the grid.

Hum is unlikely in the R.F. section of receivers that have been previously operating satisfactorily, unless it is developed in the valves themselves, and these can be singled out by grid shorts and then

substitution resorted to. Ordinary checks with valve analysers will not show up such defects.

Now we come to the third group—modulation hum. This results from L.F. modulation of the R.F. carrier wave and hence becomes evident on turning to a transmission. A convenient method of check is to connect the signal generator across the grid circuit of the last I.F. stage and inject an UNMODULATED I.F. signal. Increase the generator output until hum becomes noticeable, and if this signal is **much stronger than that of normal operation for this stage** then nothing need be done. Repeat the test with the previous stage and so on until a point is reached when a normal or less than normal signal strength produces hum. The valve of this stage should be replaced. Should hum then persist, check up on the screen-grid decoupling condenser as this may be passing ripple which will be amplified between the screen and the plate.

There is a second form of modulation hum which is only apparent when tuned to a strong "local" station. If this is occurring, first see that the electrostatic screen of the mains transformer is properly earthed. It is possible that the lead has broken connection with the metallic screen and we can form a temporary makeshift screen by connecting a 0.005 mfd. condenser of some 450 volts working between each side of the primary and earth. If this fails, try moving the receiver to another part of the room, as it may have been placed too close to concealed house wiring if this is not run in metal conduits. In rare cases it may be due to a faulty rectifier, which can be checked by connecting two 0.1 mfd. high voltage condensers from each rectifier plate to the centre tap of the mains transformer H.T. secondary.

II. "MOTOR BOATING"

The name "motor boating" is given to a form of instability at a very low frequency (anything from 25 c/sec. to 1 c/sec.) which results in a "putt-putt" sound in the speaker. Actually such low frequencies, especially below 16 c/sec., are sub-sonic but the self-oscillation is so violent that the speaker and the valves are badly overloaded and higher frequencies in the audible range are produced. The oscillation is really a series of pulses whose normal intensity is sufficient to visibly vibrate the speaker cone and may be so violent as to damage the cone suspension.

There are three main forms of this complaint which must be differentiated before remedial measures can be applied. The first and most usual type is due to pure audio feedback through coupling in a common impedance. The second is due to H.F. instability and the third is due to modulation by audio feedback.

The first is the easiest to deal with, as it is usually due to feedback through the common impedance of the H.T. supply—this being included in the anode circuits of all the valves. The impedance is that of the smoothing system and is greater the lower the frequency. It can be reduced by increasing the capacity of the output smoothing condenser. The power valve is connected across this impedance and hence sets up an A.C. voltage across it which will be passed on to the previous stage either in a de-generative or re-generative sense according to the phase of the feedback. If de-generative then the bass response will suffer and there will be a loss in volume —but if re-generative then the bass response will be increased and motor boating result. The cure for the fault is to ensure adequate decoupling of the L.F. stages (except the power valve) with an R.C. filter in the anode circuit as shown in Fig. 1. It is usual to make the R.C. value for a single audio stage equal to about 80,000 R (in ohms and C in microfarads) so that with a 50,000-ohm resistance, C could be 2 mfd., thus giving a value of 100,000. Where two L.F. stages are used the R.C. value of the first should be some 200,000 and the second as above.

Audio feedback can also occur in a single stage from anode to grid through the cathode circuit if automatic bias is used, This will occur if the capacity of the by-pass condenser is too LOW in value. To be efficient the reactance of the condenser should be about one-tenth of the value of the bias resistance at the lowest important frequency—which is customarily taken as 50 c/sec. Thus if the bias resistance is 1000 ohms the reactance of the condenser should be 100 ohms or less, and at 50 c/sec. the nearest standard value will be 25 mfd. (127 ohms) or better still, 50 mfd. with a reactance of 63.6 ohms. It is partly for the prevention of motor boating that the bias of the power valve is often taken from a tapping on a potentiometer chain in the negative H.T. line while the other valves, especially the R.F. valves, obtain theirs from separate cathode bias systems.

Where the receiver has been previously operating satisfactorily, the sudden appearance of motor boating will be most likely due to an open circuited by-pass condenser or a shorted bias resistor.

The second form of motor boating due to H.F. instability is commonest in receivers employing A.V.C., and the frequency of the beat is determined by the time constant of the A.V.C. decoupling system. Since this value is generally fairly high (e.g., 0.1 mfd. with a 1-meg. resistance = 1/10 sec.) the sound is VERY LIKE that of L.F. feedback or true motor boating. The cause is self oscillation in an R.F. valve—this sets up a big A.V.C. diode input signal which negatively biases the valves abnormally so that oscillation ceases, whereupon the A.V.C. voltage falls and the bias is reduced until oscillation starts again—in fact a kind of squeeging action. The faulty stage can be localised by inserting a milliammeter in the anode circuit of each valve in turn while the grid is shorted or detuned with a .001 mfd. condenser. If there is a variation in the anode current on doing this then the valve must have been oscillating. Check the bias resistance WHILE WARM AT OPERATION TEMPERATURE, and also the by-pass condenser for open circuit or leakage, by substitution.

The third type usually only makes its appearance on tuning to a strong station and is due to L.F. feedback to the R.F. section with resultant modulation of the R.F. carrier. The remedy is to check up on the screen-grid bypass condensers and if necessary to decouple the anode circuit. The latter remedy is not always possible as high R.C. values are required. However, it is not a common fault and is only likely to occur where the L.F. amplifier is extra good, with an excellent bass response. This can be reduced by introducing an element of negative feedback, or reducing the anode load or the value of the grid leak. The feedback can be arranged by splitting the value of the bias resistance proportionately and bypassing only the earthy end portion.

It should be noted that a similar effect is sometimes experienced with push-pull outputs if the L.F. amplification is inadequately balanced, due, perhaps, to deterioration of one grid leak or bias resistance (if the valves are separately biased).

III. H.F. AND I.F. INSTABILITY

Instability can occur in the R.F. section of a receiver whether it is new or old and is ALWAYS due to unwanted coupling between circuits separated by one or more valves. It may be due to a common impedance or to electro-magnetic or electro-static coupling between wiring and components. Stray couplings cannot be entirely eliminated, neither can any filter be perfect and these facts set a limit to STABLE AMPLIFICATION. Usually the instability becomes apparent at the higher frequencies, that is, when the amplification is greatest and the effect of stray capacities is most pronounced. But if the instability is mainly apparent at the lower frequencies then it can only be due to common impedance coupling. With ganged condensers this can be

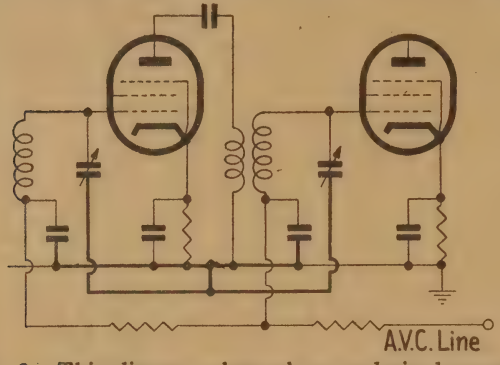

Fig. 2. This diagram shows how undesired coupling can occur between circuits that appear at first sight to be properly shielded. The heavy lines show wires that can introduce a common impedance into the two tuned circuits.

through a common earth wire to the rotors. Usually most receivers have each section separately grounded and in such cases it is possible that one of the "earths" is a high resistance spot either through a dry or resin joint, so try a really hot iron on each of them. Or again, the condenser may rely on earthing through three or more bolts and nuts—see that the nuts are actually tight as a loose connection will inevitably create a high resistance point across which R.F. voltages can be developed.

A similar common impedance coupling can be created if the A.V.C. decoupling condensers are earthed at the same spot. Where this is found it is advisable to disconnect one condenser and ground it at a separate point nearer to the valve in whose circuit it is operating. Fig. 2 shows a skeleton circuit in which the above common impedances are indicated.

If the instability occurs at the higher frequencies it is most likely due to electro-magnetic or electro-static coupling. Electro-magnetic coupling will arise if there are loose connections between a coil or valve screen and chassis, or it may be produced if the wiring of the tuned circuits has been disturbed so that wide loops have been formed, as this increases the area of the magnetic field and hence the likelihood of coupling with other circuits. Leads from the two ends of a coil to the two sides of the tuning condenser should be effectively close together so that the field round each lead cancels out the other.

Electro-static coupling will occur through stray capacities between any unscreened components and wires. For instance, the anode and grid leads of a valve should be well separated because the H.F. potential between them is large. Still more important is it to see that the anode lead of one valve is kept well away from the grid lead of a preceding valve, because, due to amplification, the H.F. potential difference is even greater in this case. As a general rule, if it seems probable that the wiring has been disturbed, individual leads should be moved about with an insulated stick to find a position of any one wire that will cause the oscillation to decrease or stop.

Instability in the R.F. section may also be produced by feedback from the L.F. section, a fact that must not be lost sight of if other remedies have failed. As we have already stated, no filter can be 100 per cent. efficient, and therefore the discriminating filter in the detector diode circuit will not block all I.F. voltage and some will inevitably leak through. For instance, to cite a common arrangement, a filter consisting of a 50,000-ohm resistor bypassed at each end to cathode by .0001 mfd. condensers, if the I.F. is 465 kc/sec. and the components are perfectly sound, the I.F. voltages leaking through will be of the order of some 6 per cent. But if any of the components deteriorate then this percentage will be considerably increased and will be amplified in the L.F. amplifier and fed back to the earlier stages. To counteract this the anode of the

(Cantinuod on page 48)

'RADIO and ELECTRONICS'

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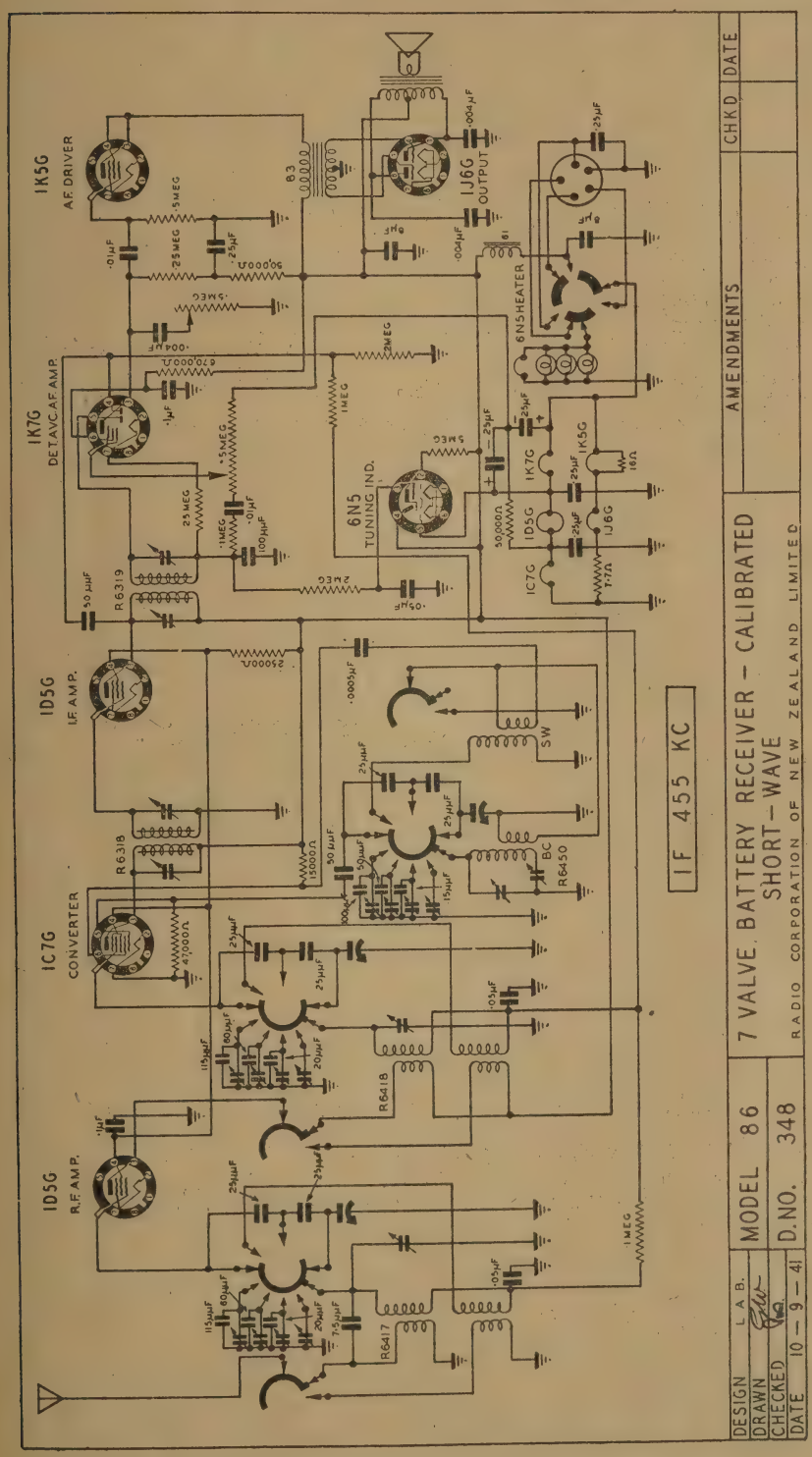


Columbus Models 86 and 86P

This receiver uses the following valve types:

Model 86	Model 86P	
1D5G	1A4	R.F. Amplifier
1C7G	1C6	Converter
1D5G	1A4	I.F. Amplifier
1K7G	1F6	Detector, A.V.C. and Audio Amplifier
1K5G	30	Audio Driver
1J6G	19	Class B Twin triode output
6N5	6N5	Magic Eye Tuning Indicator

VOLTAGE TESTS

Across filament of each valve	2v.
D.C. (measured between point indicated and chassis.)	
Plates of all valves except 1K7G	130v.
Screens of 1C7G and 1D5G's	50v.
Plate of 1K7G (approx.)	40v.
Screen of 1K7G (approx.)	20v.

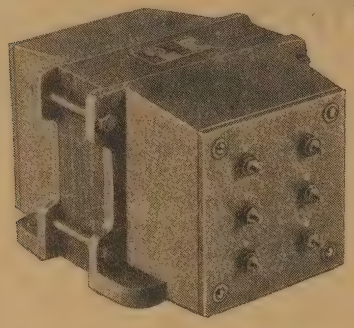
RESISTANCE TESTS

Where Measured	Approx. Resistance in ohms
Speaker transformer primary, each half	500
I.F. Transformer Coils	7
B/C Aerial primary	35
B/C Aerial secondary	5
B/C R.F. primary	70
B/C R.F. secondary	5
B/C Osc. primary	2
B/C Osc. secondary	4
S/W Aerial, R.F. and Osc. primary	0
S/W Aerial, R.F. and Osc. secondary	0

SENSITIVITY TESTS

(Microvolts input to give standard output of 50 millivolts.)

Frequency	Input to	Microvolts
455 k.c.	Grid of 1D5G I.F. amplifier	5000
455 k.c.	Grid of 1C7G	70
1400 k.c.	Aerial lead through standard dummy antenna	Under 1
1000 k.c.	„ „ „	Under 1
600 k.c.	„ „ „	1
16 metre band	„ „	2
19 metre band	„ „	1
25 metre band	„ „	1
31 metre band	„ „	1



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FREQUENCY MEASUREMENT

PART X

In the present instalment of this series we shall describe the calibration of variable frequency oscillators at multiples of 100 kc/sec. In this connection, the term "variable frequency" means "continuously variable," as in the case where tuning is provided over a wide range of frequencies.

This problem is no more difficult than calibrating any other variable frequency oscillator if a receiver is available with which to effect direct reception of the oscillator and the series of frequencies from the frequency standard. However, in most cases, receivers are not available for the range from 100 kc/sec. to 500 kc/sec, so that indirect means must be resorted to in order to indicate when zero beat is obtained between the oscillator and the various standard signals.

USE OF A BROADCAST RECEIVER

The most readily available indicating device is an ordinary broadcast receiver, which covers a frequency range of 550 to 1600 or 1700 kc/sec., as a rule. The principle used in the measurement is that of harmonic beats, which has been described before in this series; in this case, however, the identification of the oscillator frequency is performed by noting on what frequencies (over a considerable range) beats occur when the standard 100 kc/sec. series is mixed at the input of the receiver with the oscillator and its harmonics. In addition, ambiguities may be resolved by noting that under certain conditions signals do not occur at certain places on the receiver dial. In order to illustrate the principle, let us suppose first of all that our oscillator is to be set to 100 kc/sec. for calibration purposes.

If the oscillator is set to this frequency, its harmonics will lie at 200, 300, 400, 500, etc., kc/sec. Now, if the frequency standard is operated with its 100 kc/sec. series in action, the standard itself will give frequencies of 100, 200, 300, 400, etc., kc/sec. Thus, if a receiver is tuned to any one of the standard's signals, then zero beat will be obtained if the oscillator is exactly on frequency. If it is not, a heterodyne note will be heard on each of the standard frequencies. For example, if the oscillator frequency is actually 100.5 kc/sec., and one had a receiver tuned to 200 kc/sec., there would be a beat-note of 1000 kc/sec., because the standard frequency would be exactly 200, and the oscillator's second harmonic would be 201 kc/sec., giving a difference frequency of 1000 c/sec. If a receiver were tuned to 300 kc/sec., the oscillator's third harmonic at 301.5 kc/sec. would beat with the standard's 300 kc/sec. to give a note of 1500 c/sec., and so on. There are two important points to note here: First, that the pitch of the beat increases the higher the harmonic used, and, secondly, in this case a beat note is heard on **every** signal from the standard.

Thus, if we are to use a broadcast receiver for indicating purposes, the lowest harmonic which could be used would be 600 kc/sec., since, in general, 500 kc/sec. is not within the tuning range. This means that for a satisfactory measurement, the oscillator under calibration must have a certain amount of output on its sixth harmonic. This may seem a difficult thing to ask of an oscillator, but unless it is one which has been specially designed for purity of waveform, there will usually be enough harmonic output to enable the test to be carried out.

The practical point involved is that the coupling between the standard and the receiver must not be too tight, or else the amplitude of the standard signal will swamp that of the oscillator harmonic, and no beat will be heard, even if present. The best procedure is to couple the oscillator directly into the receiver, so that as much harmonic signal as possible will be received. In this connection it may be of assistance if the first valve in the receiver is slightly over-loaded, since it will then act as a harmonic generator when it is tuned to the appropriate frequencies. Thus, the standard should first of all be turned off, and the oscillator and receiver turned on and coupled together via the aerial lead. It is a good plan at this stage to tune the receiver over the band and see if signals from the oscillator can be picked up, if only weakly. If so, then no difficulty will be experienced. Next, the standard is turned on and loosely coupled to the receiver. The latter is tuned to receive the 600 kc/sec. signal from the standard, and the coupling of the latter reduced to the point where the signal on this frequency can barely be discerned. The oscillator is now tuned to as nearly 100 kc/sec. as can be estimated, and a careful search is commenced for beat-notes. This is done simply by very slow manipulation of the oscillator's tuning control. When a beat note is heard, the oscillator is set so that the note is about 500 c/sec. The receiver is now tuned to 700 kc/sec. If the oscillator has been tuned to 100 kc/sec., then a beat will be heard at this frequency also, but it will be at about 1000 c/sec. As a further check, the receiver is tuned to 800 kc/sec. If a beat note is heard here, too, and if its frequency is again higher, then it may be assumed certain that the oscillator is tuned to 100 kc/sec. Of course, one would need to be certain that the oscillator was not in reality tuned to 50 kc/sec., because this frequency will also give beats with each signal of the standard series if its harmonic output is great enough. This is hardly a likely occurrence, however, but if the design of the oscillator is such that it is a possibility, then a simple check can be made. The standard is turned off, and one harmonic of the oscillator received separately. A B.F.O. on the receiver will aid in this direction if it is available. The receiver is then carefully tuned between two of the 100 kc/sec. points on the dial. If a signal is picked up midway between the 100 kc. divisions, then this, too, is a harmonic of the oscillator which must be running at 50 kc/sec., and not 100.

The case just described is the most difficult one, and as the frequency is raised, the measurement becomes progressively easier to carry out.

CALIBRATION AT 200 KC/SEC.

Since the 100 kc/sec. case is really a special one, it is necessary to describe, in somewhat less detail, the case of another frequency which is a multiple of 100 kc/sec. This, in conjunction with the first one, completely describes the method.

For the second illustration we have chosen the case where the oscillator is to be established at 200 kc/sec. This time the oscillator harmonics will be on 400, 600, 800, etc., kc/sec. As before, the standard

will give signals spaced 100 kc/sec. apart, so that if now the oscillator is set nearly but not quite on frequency, beats will be heard at frequencies of 400, 600, 800, etc., kc/sec., but **NOT** at 500, 700, 900, etc., kc/sec. In other words, beats will be found only on the harmonic frequencies of the oscillator itself. Thus, in using the broadcast receiver, the lowest check point is again 600 kc/sec., and the next is 800 kc/sec.

In this case, therefore, the method resolves itself into finding an oscillator frequency which will give beats with the standard **ONLY** at the even 100 kc/sec. points.

OTHER FREQUENCIES

The same method used for an oscillator frequency of 500 kc/sec. would give check points at 1000 and 1500 kc/sec. on the receiver dial, while 100 kc/sec. points at higher frequencies than this will have their fundamental within the broadcast band, and therefore directly receivable by the broadcast set.

INTERMEDIATE POINTS

In calibrating the dial of a low-frequency oscillator, the most important points are the ones we have been using as illustrations, but unfortunately these are hardly enough in number to enable calibration curves to be drawn.

However, the multiple harmonic method just described can be extended to include other calibration points. For instance, supposing the oscillator range was from 100 to 300 kc/sec. (with a slight overlap at each end), so that by now we would have only three points on the calibration curve. Other suitable points, could they be used, would be 150 and 250 kc/sec. In any case, it is only necessary to make a list of the harmonic frequencies to see whether it is a practicable one for a calibration point. For example, the oscillator, if set to 150 kc/sec. would give harmonic signals at 300, 450, 600, 750, 900, etc., kc/sec. Of these, the first two are off the receiver dial, and cannot be used as check points. Of the remainder, 750, 1050, 1350, etc., kc/sec. fall at points where no signal from the standard exists. Thus, the only harmonics which will give beats with the standard series are those on 600, 900, 1200, etc., kc/sec. This result is exactly the same as would be arrived at for a fundamental frequency of 300 kc/sec., so that at first sight the method as a whole might seem ambiguous. This is not so, however, as the receiver can be used to check for the presence or absence of signals on 750, 1050, 1350, etc., kc/sec. If they are present **and no others**, then the fundamental frequency is 150 kc/sec. If no intermediate signals at all are picked up (apart from the standard) the fundamental must be 300 kc/sec.

In a similar way, 250 kc/sec. may be calibrated by listening for beats at 1000 kc/sec. and signals at 750 and 1250 on the receiver dial.

There is no theoretical limit to the extension of this method. For instance, the oscillator could be calibrated on 175 kc/sec. by listening for beats at

(Continued on p. 47.)

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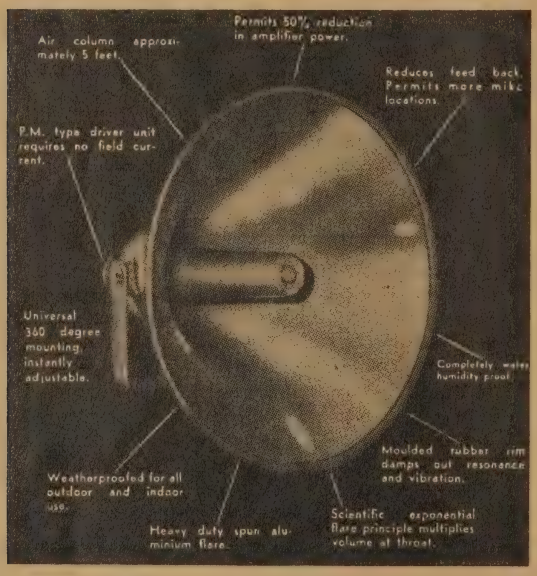
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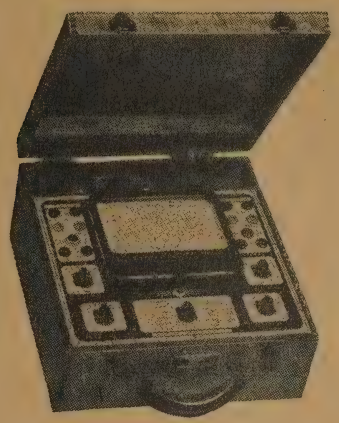

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Voltage Regulated—Bridge Type Circuit: A new departure in stabilised bridge circuit design provides a heretofore unusually high degree of direct reading VTVM accuracy, with practically complete freedom from tube variations. Utilises one type 6C5, 6X5, and VR-150. Power supply plate voltage output remains fully constant over severe line voltage variations, eliminating annoying meter shift due to A.C. input changes.

Zero-centre V.T.V.M.—Provides, in one operation, both magnitude and polarity of voltage at any test point, without reversal of test prods.

Single Master Range Selector: Provides rapid, positive selection of all functions and ranges in combination with a simplified 3 position circuit selector.

Shielded Coaxial Test Probes: Standard and circuit isolating coaxial probes furnished as original equipment. Each probe is four feet in length, utilising high-flexibility cable. Circuit isolating probe permits direct voltage measurements without disrupting apparatus under test.

Duo-balanced Electronic-bridge Ohmmeter: A new "Precision"-developed feature which fully eliminates gross inaccuracies usually associated with vacuum tube ohmmeter circuit readings. Both ends of ohmmeter scales are independently zero adjusted, providing uniformly high accuracy throughout entire scale length. A single ohms scale serves for all six resistance ranges. V.T.V.M. and Ohmmeter zero settings essentially unchanged for any series of voltage or resistance range selections.

1 per cent. wire-wound shunts and metallised multipliers employed throughout.

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± 1200, ± 6000 volts D.C.

Input resistance—13⅓ megohms from ± 3 through ± 600 volt ranges.
26⅔ megohms on ± 1200 volt range.
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Six circuit probing, zero-centre, V.T.V.M. ranges:
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Special (resistance in probe) shielded coaxial test cable allows measurements to be made in sensitive circuits without affecting receiver or amplifier performance.

Six wide-range ohmmeter-megohmmeter ranges: 6-volt internal battery powers all resistance ranges.
0-2000 ohms (20 ohms at centre scale).
0-200k. ohms (2000 ohms at centre scale).
0-2 megohms (20k. ohms at centre scale).
0-20 megohms (200k. ohms at centre scale).
0-200 megohms (2 megohms at centre scale).
0-2000 megohms (20 megohms at centre scale).

Ideal selection of overlapping ranges for all normal resistance measurement requirements, as well as for insulation resistance tests, condenser tests, etc.

Eight A.C. and eight D.C. voltage ranges at 1000 ohms per volt: 0-3-6-12-60-300-600-1200-6000 volts.

A necessary feature for standard (1000 ohms per volt) sensitivity measurements in conformance with the point-to-point voltage reading tables furnished by receiver manufacturers and in service manuals; equally valuable and desirable for tests not requiring the extreme sensitivity of the V.T.V.M. proper as well as for audio frequency signal measurements.

Seven D.C. current ranges: 0-600 microamperes; 0-3-12-60-300-1200 milliamperes, 0-12 amperes.

Eight A.C. output ranges: Built-in blocking con-

denser to 600 volts. 0-3-6-12-60-300-600-1200-6000 volts.

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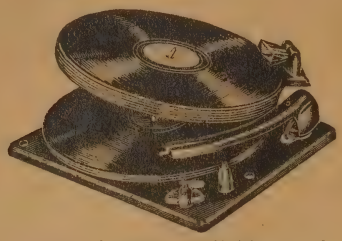

The Webster record changer is now available on the New Zealand market, and embodies many new features which will appeal to those interested in gramophone recordings. Compact and simply designed, the Webster Model 50 is easy to operate and yet is of robust construction.

It is a single-post type with a spring cushioned spindle, and will play ten 12 in. or twelve 10 in. standard records automatically with a minimum of waiting time between records. While assuring maximum protection to the finest of recordings, it will play warped or rough-edged discs automatically and will play home recordings or "inside out" records manually.

The Webster Model 50 has a fast change-cycle—about 4 seconds. A dependable heavy duty Webster motor is cushion-mounted for silent operation, and there is no audible rumble or "wow." It is easy to install, and the compact design—height 9 in. overall—makes it particularly suitable for most types of cabinets. Sole New Zealand agents are the Swan Electric Co., Ltd., Hope Gibbons Buildings, Wellington.

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The latest Weston release of interest to the radio trade, the Model 779 Type 1 Supersensitive Analyzer, will be available shortly.

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FIVE DB RANGES— −18 to +3, −6 to +15, +8 to +29, +22 to +43, +34 to +55.

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A Practical Beginners' Course

PART 13

Continuing now with the story of our first valve experiments, it will be as well to indicate some of the most suitable valve types to purchase.

As we stated last month, we are going to use a triode for our first diode experiments, simply by connecting the grid to the plate and making a diode out of it. Thus the accompanying list of valves includes triodes only, and battery-operated ones at that. This is because dry battery operated tubes are much more suitable for initial experiments than are A.C. operated types, both from points of view of simplicity and expense. Fig. 20 shows the base connections for the two types of valve socket. All types listed use one or other of these sockets. It is most important to note that these socket diagrams, as is standard practice, refer to the valve or socket pins when viewed from **underneath.**

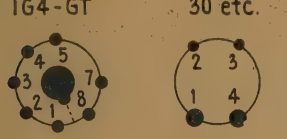

FIG. 20

Left: Fig. 20(a). Right: Fig 20(b). These diagrams show the pins to which the various elements of the valves given in the table are connected.

N.C. stands for No Connection, and is used when the pin is present, but has nothing inside the valve connected to it.

TABLE OF FILAMENT TUBES SUITABLE FOR FIRST VALVE EXPERIMENTS

Tube Type.	Fil. Voltage.	Fil. Current.	Type of Base.
1G4-GT	1.4	0.05 amp.	Octal
1H4-G	2.0	0.06 amp.	Octal
30	2.0	0.06 amp.	4-pin
A-415	4.0	0.06 amp.	4-pin
A-409	4.0	0.06 amp.	4-pin
PM2DX	2.0	0.06 amp.	4-pin

NOTE.—The last three types are old Philips or Mullard battery valves, which may sometimes be bought quite cheaply second-hand. Even if very cheap, they should be tested before buying.

It will be noted that some of the types listed have what are known as "octal" or 8-pin sockets, which are used on all modern types of valves, many of which need the whole eight pins. Those which do not, have some of the pins left out of their construction, while others are there but have nothing connected to them. The pins of an octal-based valve are evenly arranged in a circle, and it would be possible to plug the valve into the socket in eight different ways were it not for the locating pin in the centre. This wide pin goes into a hole in the centre of the socket, but can only be inserted in one way because of the raised portion or "key," which fits into a small extension of the main hole. In order to enable users to tell what electrodes are attached to what pins, the pins are numbered from one to eight. Number one is the pin to the left of the key when the valve is held upside down with the key towards you. From there the pins are numbered in a clockwise direction. The valve manuals give the connections to the various valve pins in the form of under-chassis socket diagrams. These are a diagrammatic representation of the socket from underneath, with the keyway shown towards the observer. The pin numbers are printed on the diagram, and alongside is a letter or letters representing the electrode which is connected to that pin. As an example, we have given the under-chassis diagram for type 1G4-GT, in Fig. 20 (a).

This shows that all pins are present on the valve except No. 6, which is omitted. Also pins 1, 8, and 4 have no connections made to them. Pins 2 and 7 are the filament terminals, pin 5 is the grid, and pin 3 is the plate of the valve. Having a standard octal socket, it is now possible to wire it up to suit any circuit for which a 1G4 may be used.

Fig. 20 (b) gives the under-chassis socket connection for any directly-heated triode which uses a four-pin American type base. (The English four-pin base is different from this.) This base is numbered as shown, with the fat pins nearest the reader. The left-hand one is called No. 1, and the rest are numbered in a clockwise direction as before. No. 2 is the plate and No. 3 is the grid, while Nos. 1 and 2 are the filament connections. It is useful to know that **all** directly-heated triodes use this arrangement of base connections.

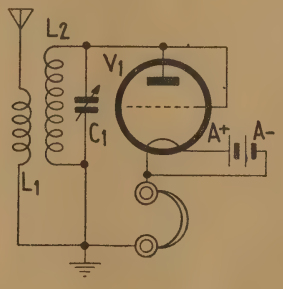

Fig. 21.

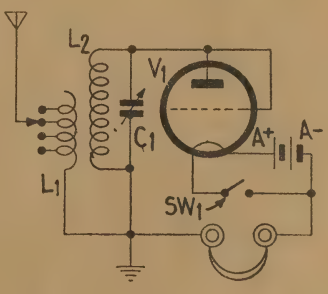

Fig. 22.

THE FIRST VALVE CIRCUIT

Having found out how connections may be made to the valve socket, we are now in a position to wire up our first set using a valve. This is shown in Fig. 21. If the circuit is examined carefully and compared with Fig. 3 ("Beginners' Course," Part IV, "Radio and Electronics," November, 1946), it will be seen that the two circuits are really identical. The only difference is that the crystal detector has been replaced by the valve V_1 and the battery which heats its filament. The valve is connected as a diode by connecting the plate and grid bias together at the socket terminals.

Many articles intended for beginners try to make things easier by printing a "pictorial" circuit diagram, in which pictures of the components are used, with connecting wires drawn in instead of the plain

theoretical diagram. In this course we are not going to do this, for the following reason. Although such pictorial circuits do make things a little easier for the very beginner, they are not a proper method of instruction, for the simple reason that sooner or later it becomes necessary to learn how to use standard circuit diagrams. At this stage, the unlearning of the pictorial circuits is much more difficult than is learning the right way in the first place. For instance, in the present case, all that we need to know in order to build the circuit of Fig. 21 is (a) what type of valve is to be used and (b) what its under-socket connections are. This information we have already given in Fig. 20, so that anything like a pictorial wiring diagram is quite unnecessary.

The only thing about Fig. 21 that has not so far been explained is the meaning of the terms A+ and A— with which we have labelled the filament battery. This labelling is a survival from the early days of radio, when all valves were directly heated and designed for battery operation only. The battery used to heat the filament was called the "A" battery, and the one used to apply a positive voltage to the plate of the valve was called the "B" battery. Each battery, of course, has a positive and a negative terminal, so that on circuit diagrams these are always labelled A+, A—, B+, and B—, meaning "the positive terminal of the A battery," "the negative terminal of the A battery," etc. Where battery valves are used to-day, this naming is still used, because it is still just as important as ever to have the batteries connected the right way round in the circuit, and to have the right battery connected in the right place.

METHOD OF BUILDING FIG. 21

In the old days, all valve sockets were of the type now called "base-board mounting," and very seldom seen. These sockets were arranged with small terminals instead of solder lugs, and had small holes which enabled them to be screwed or bolted to the base-board. Modern sockets, however, are of the wafer type. That is, they consist of a small "wafer" of insulating material, underneath which are the lugs which enable soldered joints to connect the circuit wiring to the valve pins. These sockets are really intended only for mounting on a metal chassis. However, they can be used for experimental sets with a base-board by screwing them on to two small pillars about an inch high. This allows the lugs to clear the base-board and makes a rigid mounting for the socket when the pillars are screwed into the base-board.

The first step is to procure a valve from the list above, and then the appropriate type of socket for it. The mounting pillars can be small pieces of dowel rod which are first screwed to the base-board the correct distance apart and then have the socket mounted on them. It is best, however, to attach the wiring to the socket before screwing it down to the pillars, as there is then much less likelihood of the wrong pins being used. In this case, the socket is wired up as follows: First, the grid and plate pins on the socket are connected together by soldering a short piece of wire between them. Next, a single piece of wire is soldered to one filament pin. This will be the wire to go to the negative terminal of the battery, A—. Now, two pieces of wire are soldered to the remaining filament pin. One of these will go to the positive battery terminal A+, and the other will go to the Fahnstock clip used for one of the headphone connections. Finally, the wire from the top of L_2 and C_1 is taken to the valve socket and soldered on to either the plate or the grid pin. This completes the wiring of the socket, which may now be screwed down on to its supporting pillars.

In order to turn the set on and off, one of the A battery leads may be connected and disconnected at the battery terminal.

As mentioned above, Fig. 21 is exactly equivalent to Fig. 3, except that the diode detector has replaced the crystal detector. Any of our previous crystal circuits can be modified to use the diode detector simply by substituting the valve and A battery for the crystal, as has been done in Fig. 21. As an example, Fig. 22 shows the circuit of Fig. 5, in which the same substitution has been made. In Fig. 22 also we have introduced one more component Sw_1, which is connected in the negative lead to the valve and makes a more convenient means of turning the set on and off than simply using a battery terminal, since the use of a switch leaves the wiring completely undisturbed when the switching is taking place.

USE OF VARIOUS TUBES

The table above gives for each tube type its rated filament voltage and current, and it has probably been noticed that the rated voltages do not coincide with the voltages available from torch-cells, which give 1.5 volts each. Thus, two in series give 3 volts,

(Continued on p. 48.)

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precaution with high-mutual-conductance tubes, and prevents oscillation at some super-audible frequency without having any appreciable effect on the frequency characteristic. Apart from this and the bias circuit, the output stage requires no special mention.

(2) The Cathode-follower Stage

The unusual practice of having separate filament windings for these tubes has already been commented upon, together with the 1-megohm leaks between heater and cathode. It should be emphasised that in this part of the circuit particularly, the component values should be strictly adhered to. In the initial development work, much experimentation was done in order to find out whether the signal handling capacity of this stage could not be still further increased, and the values of bias, grid, and load resistor finally chosen represent the optimum. Any departure from these values will result in a lower voltage handling capacity in this stage. The high values of coupling condenser used throughout the amplifier are necessary in order to keep up the low-frequency response. The need arises from the low values of grid leak used everywhere except in the cathode-followers. These values in turn are dictated by the necessity for keeping up the response at very high frequencies. Thus it can be seen that alteration of any one value in the amplifier can have quite drastic repercussions on the performance as a whole.

(3) The Voltage Amplifier and Paraphase Stages

The only noteworthy point about the 76 stage is that here also the grid resistors are limited to 100,000 ohms. This is in the interests of high-frequency response, for the total operating input capacity of the 76 is surprisingly large—in the vicinity of 30 mmfd. As a result, the use of the normal 0.5 meg. grid leak at this point would tend to cause quite bad high frequency loss—bad, that is, when we are attempting to achieve a flat response up to at least 20 kc/sec. For this reason, too, it will be noted that a little gain has been sacrificed by using 50k. plate-load resistors for the 6C5's.

A pre-set balancing control has been incorporated in the paraphase stage. This can be, as drawn, a 100k. potentiometer, or, if preferred, a 50k. fixed resistor in series with a 50k. pot. at the earthy end of the pair. The latter arrangement will be slightly less critical to adjust, but the normal taper of carbon potentiometers takes care of this point, even if a 100k. pot. is used.

In an earlier article we enlarged upon the subject of balancing paraphase stages, so that it is not proposed to do so here. It should be pointed out, though, that in this amplifier much the best procedure is first to ensure that the DA30's are matched, and then to balance the paraphase stage by testing at the grids of the output tubes. If desired, the 6SN7 mixer stage can be used to test for balance, as described in an article which appeared in our pages recently. All that is necessary is to detach the input lead to the top 6C5 in the circuit diagram and provide a temporary input potentiometer for this tube. Then a pair of headphones is connected across the 100k. output potentiometer of the 6SN7, and temporary leads are taken, one from each DA30 grid to one 6SN7 grid, **via the 0.05 coupling condensers**. This last point should not be forgotten, as if the grids were directly connected there would be a partial loss of bias on the DA30's, owing to the positive D.C. potential at the 6SN7 grids.

When these connections have been made, a moderate or small input is applied to the 6C5 grid at some frequency in the middle audio range, and the balancing potentiometer R_{20} is simply adjusted for minimum output in the phones.

The above procedure will hardly be necessary if an oscilloscope is available, since in that event all that needs to be done is to clip the scope's input lead first to the grid of V_9 and then to that of V_{10}. The lengths of trace obtained in the two positions are equalised by manipulating R_{20}, and the job is done.

INITIAL TESTING

With triodes the size of DA30's, it is very necessary to ensure that the plate voltage and grid bias have the correct values before proceeding to pass signals through the amplifier. Also, it is essential to ensure that by some accident or other the output stage is not oscillating. These things, in conjunction with the fact that in an amplifier designed for the highest quality, balanced output tubes are required, make it imperative to carry out initial tests with a plate milliameter, which may be dispensed with when everything has been found to work properly.

The first point to check is the matching of the output tubes. The procedure is as follows: First of all, an ohm-meter is used to set the bias-balancing resistor (R_7 on the power supply diagram) to centre scale. Next, R_5 and R_6 are set (also with the ohm-meter) to identical values, which in this case should be 1530 ohms.

A milliameter is now placed in the plate circuit of each DA30 in turn, and a check made for equality of plate currents. If some slight difference is observable, the bias-balancing potentiometer is adjusted until the tubes show equal plate currents.

The next test is that of plate and bias voltage. A voltmeter of at least 1000 ohms per volt is required, and measurements are made at the centre-tap of the output transformer and at the filament centre-taps of the DA30's. The latter measurement gives the apparent grid bias voltage, which is subtracted from the total supply voltage to give the working plate voltage. With the circuit constants given, the supply voltage should be close to 500 volts, the bias approximately 100 volts, giving a plate voltage of 400.

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As long as these figures are approached fairly closely, with a total plate current of 125 ma., all is well.

However, if wider divergences are found, there is a strong probability that something is wrong—either oscillation of the output stage or else grid emission in one of the tubes is causing loss of bias through grid-current. If either of these faults is suspected, there are two tests which can be applied.

The output stage, if oscillating, will probably be doing so at some super-audible frequency, and the presence of oscillation can be checked by taking an oscilloscope lead to the plate of either tube; with no input voltage applied and no oscillation, there will be zero output, as shown by no deflection on the C.R.T.

A faulty tube will not in general cause oscillation, and, should this be found, the reason is most likely to be that of feedback into the earlier stages through the presence of long plate leads to the output transformer. We have mentioned this fault, not because it is likely, but because it is possible, and will cause complete ruination of the quality of the output if it does occur. The 1000-ohm grid-stoppers are a worth-while insurance against its occurring.

Loss of grid bias through grid current in one or both tubes is indicated if the plate current does not check with what should be flowing, if the measured values of plate voltage and grid bias are assumed, and applied to the curves for the valve. It is possible for the actual grid bias to be much less than that measured by the method above, if grid current is flowing, so that the tubes appear to have the correct bias (or even much more than this) and yet the plate current is far higher than it should be.

This trouble, also, is unlikely to be encountered, but is merely mentioned in case someone should be unlucky enough to strike it. In order to spot such troubles immediately should a tube fail while the amplifier is in use, it is good practice to insert a permanent milliameter reading the output stage's total plate current.

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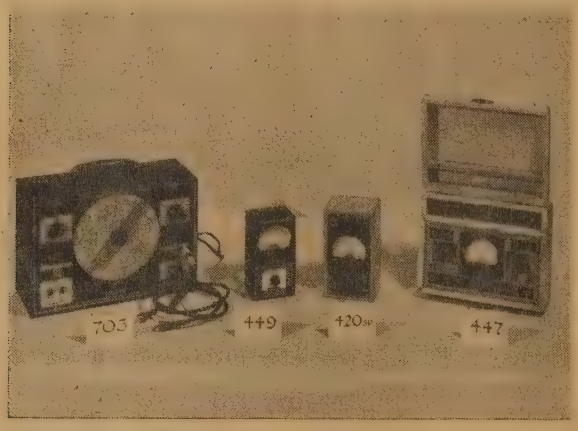

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HIGH POWER OUTPUT

Under the operating conditions specified in this article, namely, pure class A, both as to bias and load impedance, and with 400 volts on the plates of the DA30's, the rated power output should be 16 watts for zero second harmonic distortion and a very small quantity of third harmonic. If distortion up to 5 per cent. total is permissible, the maximum power output will be over 20 watts.

However, if even more than this is required, it is possible to obtain it by the simple expedient of increasing the power supply voltage to 634. This provides the maximum rated plate voltage of 500, with 134 volts of bias. In order to run the amplifier under these conditions, the only change necessary apart from providing the higher supply voltage is to alter the values of the DA30 bias resistors. In this case the required resistance is 2230 ohms per valve. Taking off the 100 ohms placed in each leg by the adjusting potentiometer, this leaves 2130 ohms for each valve. Thus the resistors R_5 and R_6 should each be adjusted to this value, the balancing potentiometer R_7 remaining at its previous value of 200 ohms.

RESULTS OBTAINED

The performance of the amplifier on a loudspeaker load is really outstanding on account of the excellent frequency response (which is determined almost solely by that of the output transformer) and the very low distortion at what may be termed normally high listening levels, i.e., with an **average** power output of about six watts, running up to considerably more than this on peaks. It is not possible to give performance curves on the amplifier at this stage, but it is hoped to do so in a succeeding issue. However, a few figures are available which should be of interest. With measurements taken at the grids of the DA30's, at which point the output transformer does not enter into the results, the frequency response was found to be completely flat from 15 to 10,000 c/sec., 0.25 db. down at 20 kc/sec., 1 db. down at 42 kc/sec., and 3 db. down at 82 kc/sec.

After this point in the amplifier, only the output transformer can modify the frequency characteristic, with the result that the amplifier can be used with

(Continued on p. 48.)

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THE MYSTERY OF THE DARK ROOM

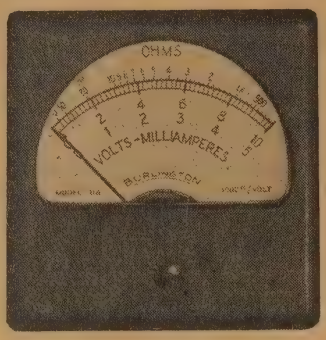
Poor old Jenkins was distinctly shaken to the core and damn near exploded as he dumped his latest purchase down calling it a box of junk. It had no kick in it at all and he'd be better off with a crystal set and so on, etc., etc. Well, we connected up, after settling the various valves back in their sockets, and switched on—full volume nearly blew the old buster out of the joint—there didn't seem to be much cause for wrath there! So we paddled round to Jenkins's place to try the set and sure enough it didn't exactly sparkle. We checked the mains supply and that was up to standard—then had look-see at the ground lead and that was all in order. Next we got a ladder and visited the loft where the aerial was installed and checked connections and found all O.K. It was pretty dark in there and twice we damn near went through the ceiling, so a light was definitely indicated. Jenkins produced a torch which I played with while he went below to get busy with a kettle for a spot of soothing.

Presently he called me down to sample it, after which we switched on the set and, boy, you should have seen his face! He damn near bowed me off his place as if I was the King of the Congo—I was black enough anyway—wonder if I could add the price of a slap up bath to the account?

SOLUTION TO LAST MONTH'S PROBLEM

Didn't I tell you what my assistant, Jack, had done? You remember my mentioning those close-fitting split screening cans for the valves? Well, when he put them back on, apparently he had some difficulty with the I.F. bottle as it was so close up to the tuning condenser frame, and somehow or other he had managed to crack the glass envelope and of course couldn't see the damage because of the can and hence assumed that the valve was still O.K. as previously tested. Agranoying, wasn't it?—still, experience is a good teacher and I don't expect he will do it again—or anyway he won't tell me!

Any attempted solution should be posted so as to reach our offices not later than the — of the current month.



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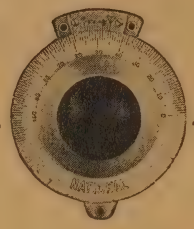

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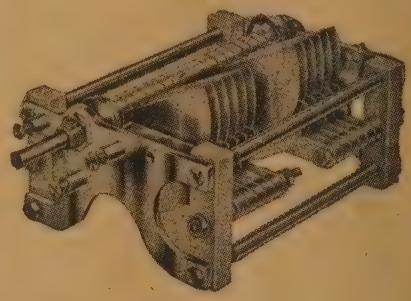
Prices are, as yet, not available, but indications are that they will be exceptionally moderate. Also available are a range of Transmitting Condensers by Hammarlund and National and Midget Condensers by Hammarlund and Polar.



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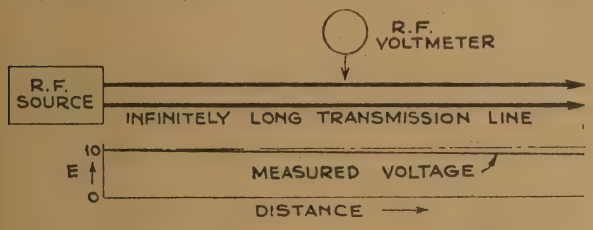
TRANSMISSION LINES

A *transmission line* is a means of transferring R.F. energy from a source to a load in an efficient manner.

For simplicity, most of the illustrations in this article show parallel-wire transmission lines, but the information also applies to coaxial lines. The similarity between a section of parallel-wire line and a coaxial section may

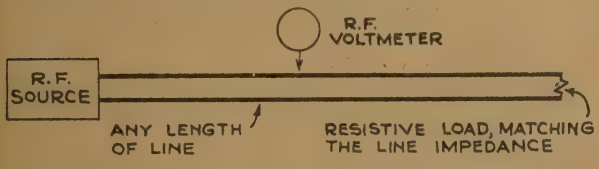
be seen by rotating a parallel-wire section about one wire so the outer arm forms a cylinder as shown.

The *R.F. voltmeter,* referred to in the text, usually consists of an R.F. rectifier and meter which indicates the rectified peak amplitude of the R.F. voltage at any point along the line.



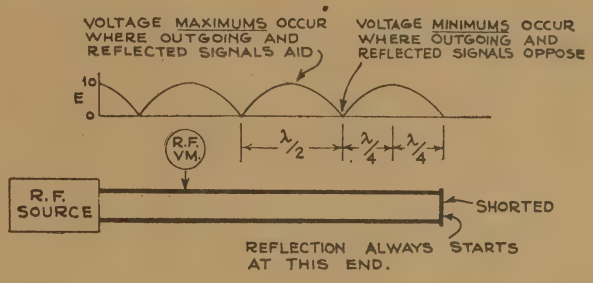
STANDING WAVES ON LINES

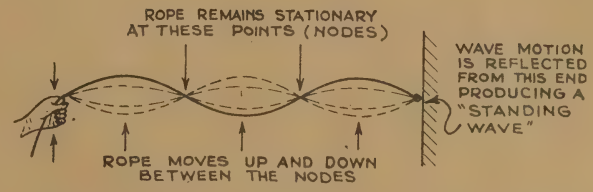
In this illustration, an R.F. source is feeding R.F. energy into a transmission line. If the line is infinitely long, the signal never reaches the end, and therefore cannot be reflected, so there are no "standing waves." The R.F. voltage measured along the line gradually decreases due to losses in the line.



If the line is *terminated* in a resistive load that matches the line impedance (also termed "surge" or "characteristic" impedance), the outgoing signal is completely absorbed by the load. As a result, there are no reflections and no standing waves, and the voltage is essentially the same at all points along the line.

If the load is not resistive and matched to the line impedance, it reflects signal back into the line. *The combination of the outgoing and reflected signal produces a standing wave on the line.*




ROPE REMAINS STATIONARY AT THESE POINTS (NODES)
WAVE MOTION IS REFLECTED FROM THIS END PRODUCING A "STANDING WAVE"
ROPE MOVES UP AND DOWN BETWEEN THE NODES

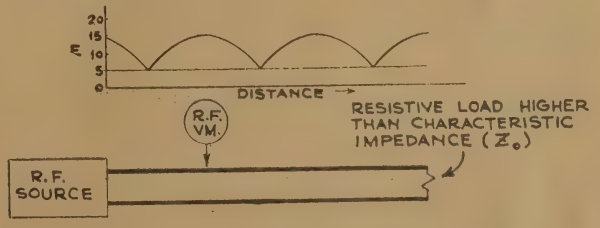
This analogy shows standing waves produced by wave motion reflection on a rope. A similar analogy can be made to standing waves of sound along a pipe.

STANDING WAVE RATIO

$$\text{The standing wave ratio} = \frac{\text{Minimum Voltage}}{\text{Maximum Voltage}}$$

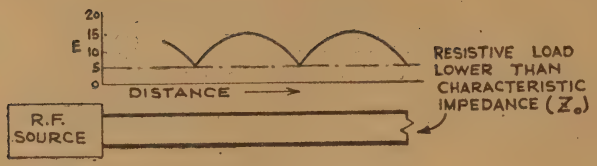
This ratio indicates the ratio of mismatch of the load impedance.

In the example shown below, the voltage at minima is 5, and the voltage at maxima is 15. The ratio is 5/15 or 1 to 3.

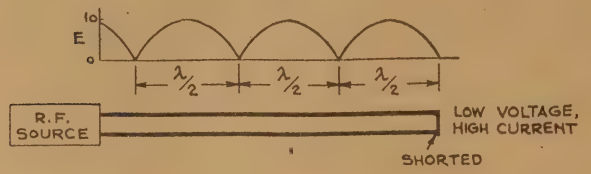


Hence, the load impedance is either 3 times larger than the line impedance, or one-third of the line impedance. In the foregoing example, the voltage at the load is maximum, so the load impedance is higher than the line impedance.

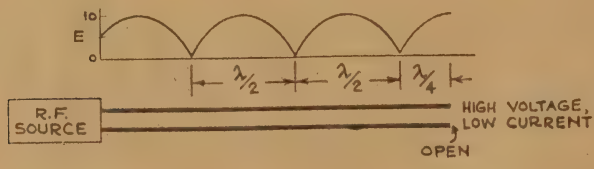
IF THE LOAD HAS AN APPRECIABLE REACTIVE COMPONENT THE STANDING-WAVE RATIO IS ONLY A ROUGH INDICATION OF THE IMPEDANCE MISMATCH. THIS CAN BE SEEN FROM THE CURVES IN THE APPENDIX.



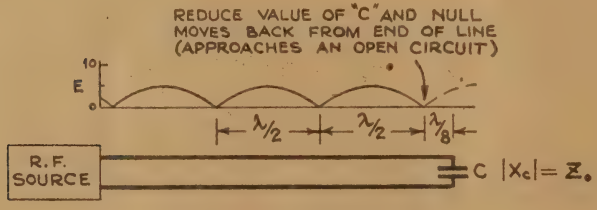
In the example shown above, the voltage at the load is minimum, so the load impedance is lower than the line impedance.

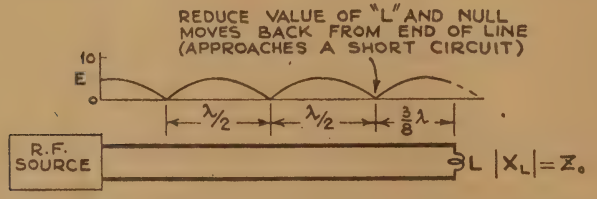


If the end of the line is shorted, the voltage at the short is low and the current is high. The first voltage minimum occurs a half-wave back from the end of the line.



If the end of the line is open, the voltage at the end is high, and the current is low. The first voltage minimum occurs a quarter-wave back from the end of the line.



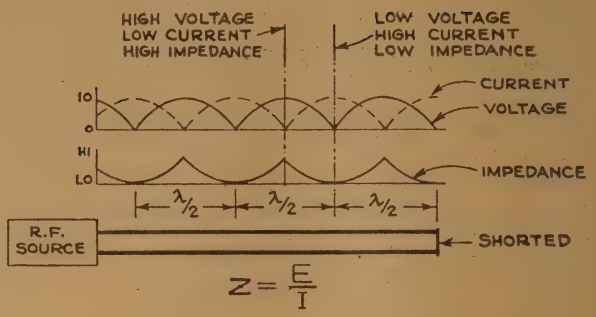


For loads containing reactance, the standing wave will be shifted, depending on the nature of the load.

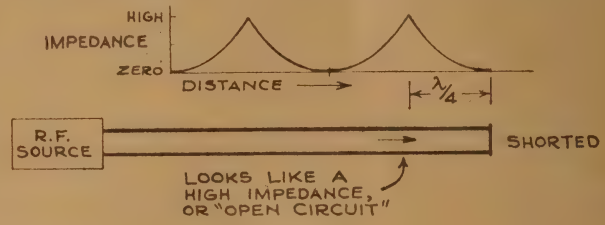
Often, it is desirable to speak of electrical degrees rather than fractions of a wave-length.

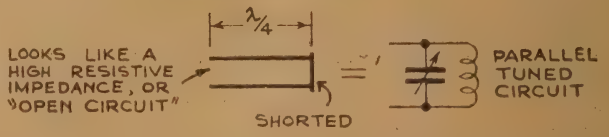
IMPEDANCE AT DIFFERENT POINTS ALONG THE LINE

The impedance at any point along the line is determined by the ratio of voltage to current at that point:



If the voltage is high, the current at the same point is low, and therefore the impedance at that point is high.





If the line has low losses, and no energy is absorbed by the termination, the low-impedance points are equivalent to short-circuits, and the high-impedance points are equivalent to open circuits. If there is energy loss in the line or termination, the impedance tends to become more uniform along the line. *When the load matches the line, the impedance becomes uniform along the line, and is equal to the "characteristic" impedance.*

It should be noted that an open circuit, a short circuit or a pure reactance at the end of the line will not absorb power. Standing waves will therefore exist with such loads.

SUMMARY—EFFECT OF LINE TERMINATION

(1) If a line *of any length* is correctly terminated with a resistive load that matches the line impedance, there are no reflections, and no standing waves.

(2) If a line is not correctly terminated, the signal is reflected back from the load and this results in standing waves.

(3) The value and nature of the load determines the *ratio* of voltage at maximum and minimum points along the line, and also the *position* of these maximum and minimum points.

In most applications where a line is used to connect a signal source to a load (for instance, to connect a transmitter to an antenna) it is generally desirable to make the load match the line. *If the load is not matched, the length of the line becomes critical,* and incorrect length may affect the power output and frequency of the source. *When the load is matched to the line, the*

length of the line is not critical. ("Matching" means that the load must be resistive and equal to the line impedance.)

RESONANT SECTIONS

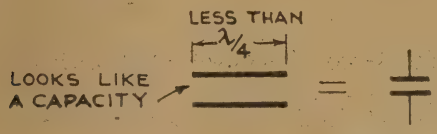
Quarter-wave and half-wave sections and their action as tuned circuits will now be considered. This action will be explained on the basis of change in impedance produced by standing waves along an opened or shorted line.

When sections of line are used as tuned circuits, their action depends on the existence of reflections and standing waves to produce the effect of high-impedance and low-impedance tuned circuits. Therefore, sections of lines, when used as tuned circuits or transformers are either effectively shorted or opened at the end to produce the maximum standing-wave ratio and the highest or lowest possible input impedance, as desired in the application.

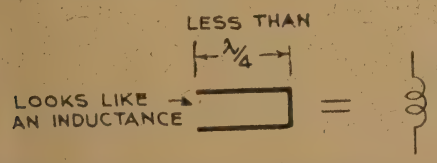
QUARTER-WAVE SHORTED SECTION

The quarter-wave shorted section at the end of the line looks like a high impedance to the input signal, and being tuned, it is resistive. The equivalent conventional circuit is a parallel-tuned circuit, for it also has high resistive impedance at the resonant frequency.

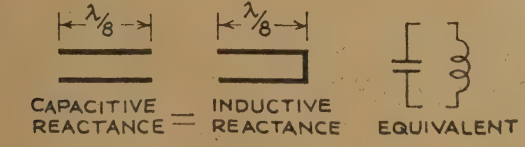
The action of a quarter-wave section may also be explained as follows:

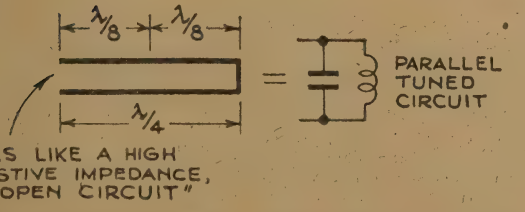


A section of line open at each end and less than a quarter-wave long acts like a capacity.

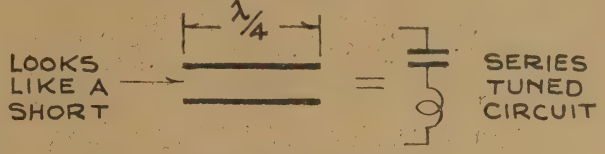


A section of line shorted at one end and less than a quarter-wave long acts like an inductance.





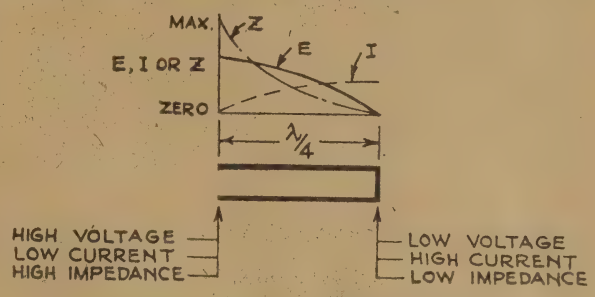
The capacitative reactance of a section of line one-eighth-wave long, open at the ends, is equal to the inductive reactance of a section of line one-eighth-wave long, shorted at one end: The values of these reactances are equal to the "characteristic" impedance. (The "characteristic" or "surge" impedance depends on the size and spacing of the conductors.)



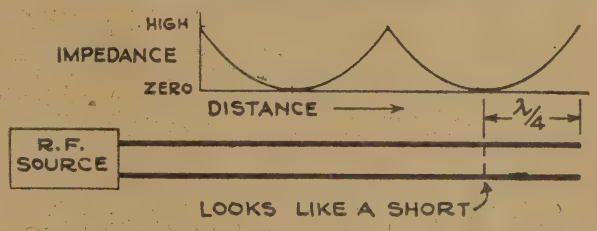
If the two sections are combined, the result is a resonant circuit that has high-resistive impedance, like a parallel-tuned circuit.

(This example is given because it is simple to visualise. Naturally, any two sections that add in length to equal one-quarter wave electrically will have equal reactance and will produce the same result.)

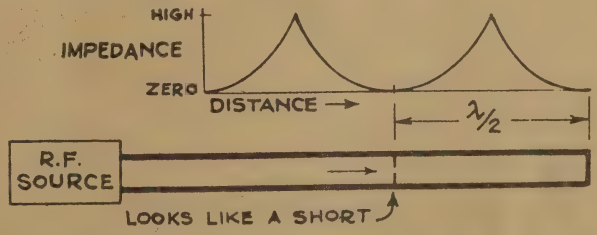
The voltage, current and impedance relations for a quarter-wave section are shown below:



QUARTER-WAVE OPEN SECTION



The quarter-wave section at the end of the line has very low input impedance, and being tuned it is resistive. It is equivalent to a conventional series-tuned circuit.



The half-wave shorted section at the end of the line also has low resistive input impedance. It corresponds to a series-tuned circuit.

(To be continued.)

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VALVE CURVES IN CLASS A AMPLIFIER DESIGN

PART III

So far in this series the general question of valve curves and load lines has been discussed, and it has been shown how these can be used in the design of resistance-coupled triode amplifiers. We come now to the consideration of the same method in connection with power triodes.

TRIODE POWER AMPLIFIERS, CLASS A

In Fig. 5(b) we have the skeleton circuit of a triode power amplifier which uses a transformer for coupling the output to the load, or device which is to absorb the power produced by the amplifier tube. This load may be a loudspeaker, a succeeding power amplifier, or a modulated amplifier—in fact, anything for which power at audio frequencies is required, and which has a more or less specified impedance. The transformer is necessary so that the transfer of power may take place as efficiently as possible from tube to load, and in order that the load presented to the tube may be the optimum. Here, the impedance of the device absorbing power is Zl, and this is transformed into an equivalent load Z¹l in the plate circuit of the valve, where Z¹l is given by:—

$$Z^1l = Zl. \left(\frac{Np}{Ns}\right)^2$$

where Np/Ns is the turns ratio of the transformer.

The point that must be brought out here is that a suitable reflected load impedance Z¹l may be used to give a load-line on the valve curves, just as though it were a real resistor in the plate circuit. This impedance can be chosen to have any value that is most suitable for the tube, and irrespective of the actual impedance Zl of the loading device. When, with the aid of the valve curves Z¹l has been chosen, it is only necessary to choose the correct turns ratio for the output transformer in order that Zl may simulate the required load impedance Z¹l at the plate of the valve.

The load-line diagram for a transformer-coupled stage looks rather different from the one for the resistance-coupled case, but is derived in almost exactly the same way. It demonstrates clearly one of the advantages of the transformer-coupled stage, namely, that the actual voltage at the plate of the valve is that of the supply (or very nearly), since the voltage drop in the transformer primary is practically zero. In the resistance-coupled case, a large proportion of the available H.T. voltage is dropped in the load resistor, so that the full available voltage is not impressed on the plate of the valve.

In Fig. 5 (a) we have the operating point Q determined as usual by the plate supply voltage Eh.t., which in this case is the same value as Eq, the voltage at the plate. (It is slightly less, of course, owing to the D.C. resistance of the transformer primary, but to simplify matters we are neglecting this.) The other factor which determines the operating point Q is the grid bias, as before. Thus, if the manufacturers' recommendations are adhered to, we have the point Q already defined for us, and it can be marked on the graph.

This time the load-line is drawn with the known operating point Q, as the starting place, for here the plate voltage is independent of the value of the load. The load-line must pass through Q and have a slope of the correct value to represent the desired load resistance.

However, the problem of designing a triode output stage from the valve curves is the reverse procedure, and so will be described in that way. Once an apparently suitable operation point has been chosen, the problem is to choose the correct load resistance, and this can be done in the following way: A trial load-line is drawn through Q at a slope which gives something like the largest plate voltage swing and plate current swing at the same time. Looking at Fig. 5 (a) as an example, we see that a plate voltage Eq has been chosen and a grid voltage of — 40. Thus the operating point Q is to

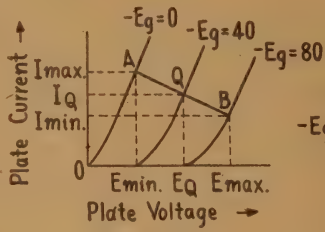

Fig. 5(a).

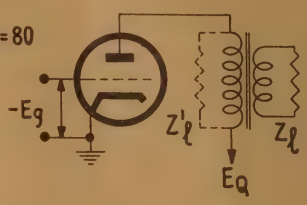

Fig. 5(b).

be found at the intersection of the curve for — Eg = 40, and the line representing a plate voltage of Eq. The trial load-line AQB has been drawn to cut the grid voltage curve for — Eg = 0 at A, and that for — Eg = 80 at B. The currents and voltages at A and B have been labelled as before, giving as they do the minimum and maximum value of plate voltage and current reached during the cycle of input voltage.

The trial load-line having been drawn and labelled, the power output may be calculated from the formula:—

$$Po = \frac{(E\ max - E\ min)\ (I\ max - I\ min)}{8}$$

The next step is to estimate the amount of distortion present. This may be done by measuring AQ and QB, and applying the ratio AQ/QB to the graph, Fig. 3, which will give a direct reading of the percentage of second harmonic distortion.

If desired, the result may instead be obtained from the formula:—

$$\text{Per cent. 2nd harmonic} = \frac{AQ - QB}{2(AQ + QB)} \times 100$$

The second and third harmonic distortion can also be estimated by the "five ordinate" method, which will be described shortly in connection with pentode power amplifiers.

When power output and distortion have been estimated from the trial load-line, one must decide whether (a) the power output is great enough for the purpose in hand and (b) whether the distortion at maximum power output, as calculated, is larger or smaller than can be tolerated for the application in mind.

There are now several cases which have to be considered in detail, and these will be treated individually. However, it should be pointed out that

in the succeeding discussion, one fact is the basis of the design procedure past this point. It is this: **That increasing the load resistance will, in general, reduce the power output and distortion simultaneously, and vice versa.**

(1) More Power Output than Required

If after the initial trial load-line this condition is found to hold, there are two ways in which to proceed. First, the existing conditions can be chosen with the knowledge that less than maximum grid swing will give the required power output, with less than the calculated figure of second harmonic distortion. Alternatively, a higher value of load resistance can be chosen, using the original operating point. This will give a lower maximum power output at a smaller distortion figure. Which is the best practice to follow depends on which condition of operation gives least distortion at the required power output.

This point can be settled by finding the distortion produced under the two conditions.

In the first case, the same load-line as before is used, but the grid-swing is reduced to the point where the desired output is required. Exactly how great this input signal is can be readily calculated from the relation

$$e_2 = e_1 \sqrt{\frac{P_2}{P_1}}$$

Where e_2 is the required peak grid voltage, e_1 is the peak grid voltage previously used to calculate P_1, the trial output power, and P_2 is the required output power. Next, the points on the load-line where it is cut by the curves for $(Eg + e_2)$ and $(Eg - e_2)$ are determined, and the power output and distortion are calculated as before.

In the second case, a new load-line is drawn through Q, more nearly horizontal than the original one. It will therefore represent a higher load resistance. The same procedure as before is followed for finding the power output and distortion at maximum grid swing, and the results are then compared with those obtained from the original load-line and the reduced grid swing.

The best condition to use is the one which the calculations show to give least distortion at the required power output.

(2) Insufficient Power Output.

If the trial load-line shows that insufficient power is delivered, a new load-line must be tried with more slope than the original one, representing a lower load resistance. The new line is therefore drawn, and the distortion and power output are calculated again. If the power output is great enough and the distortion not too great, the amended load-line is correct and gives the required load for the tube. The value of load resistance in ohms is then given by

$$Rl = \frac{1000.\ (E\ max - E\ min)}{(I\ max - I\ min)}$$

where E is in volts and I in milliamps.

(3) Too Much Distortion

If the power output given by the trial load-line is just sufficient but the distortion is too great, increasing the load resistance in the manner described above will decrease the distortion, but will lessen the power output as well, so that in this case the only cure is to choose a different operating point or else a different valve.

Whether or not a larger valve will have to be employed under these circumstances depends largely on how close the original operating point was to the maximum plate dissipation of the tube. The plate dissipation under given conditions is calculated from the chosen operating point only, and is given by

$$\text{Plate dissipation} = 1000.\ I_Q.\ E_Q \text{ watts}$$

where I_Q is in milliamps and E_Q in volts.

If the original operating point gives a plate dissipation that is well within the maximum rating for the tube, then the same tube may be used with higher plate current than was originally allowed for, as long as the maximum rated plate dissipation is not exceeded.

With a new operating point tentatively chosen on the above principle, the job of estimating the new power output and distortion level can be done again, exactly as before. If it is impossible to realise the required output when the tube is running at maximum dissipation, it is imperative to choose a larger tube or to use two tubes in parallel.

Class A Triodes in Parallel

If it is decided to use tubes in parallel to achieve the required power output, the curves for a single tube may be used, if the current scale is multiplied by a factor of 2 and all calculations are made on

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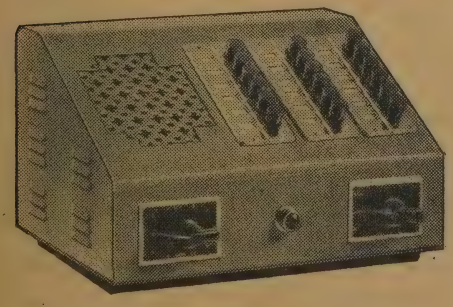

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this new current scale. It should be noted that if the scale is doubled in this way, a load-line already drawn on the graph will now represent one-half the resistance which it represented before the current scale was doubled.

In short, two tubes in parallel may be regarded as a single tube, of the same amplification factor, half the plate resistance, and twice the mutual conductance of the single tube, and doubling the values on the plate current scale looks after these alterations automatically.

CHOICE OF CONDITIONS

If, as sometimes happens, no "typical operating conditions" are available on the tube it is desired to use, only the plate family of curves being given, it is possible to gain a good idea of where the operating point should lie from the following formulae:—

$$-Eg = 0.675\ Eb/\mu \quad \text{and}$$

$$I\ max = 2I_Q$$

In the first of these formulae, $-Eg$ is the grid bias voltage, Eb is the plate supply voltage, and μ is the amplification factor of the tube. In the second formula I max and I_Q have the same meanings as used previously.

It will be noted that these two formulae give a load-line, because the first fixes the operating point, Q, and the second fixes the point B. Thus a line drawn through B and Q to cut the $-Eg = 0$ curve is in A. The load-line is then AQB, as before, and power output and distortion can be estimated from it.

(To be continued.)

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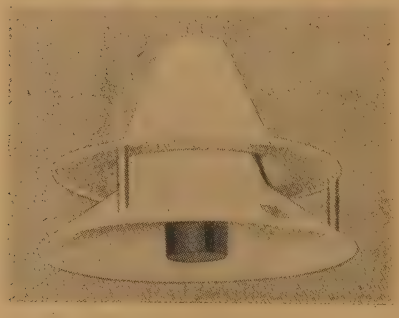

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THE "CIRCORN"

The CIRCORN is a re-entrant horn loud-speaker with one reflex point: the last section of the horn is flared outwards, the first section has a deflector added to it, the result is an annular opening, or mouth, giving horn type results and a 360 deg. distribution. The CIRCORN could also be described as a "Radial Diffuser Horn." The expansion of the horn is radially throughout and the design is approximately in accordance with an exponential law.

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POST-WAR RADAR SEEN IN WELLINGTON

Last month (June) was notable for the first appearance in New Zealand waters of a ship bearing the latest marine radar equipment.

The ship was the Port Line's new vessel, "Port Pirie," which was on her maiden voyage, and the radar equipment referred to was a sample of one of the first radar sets to be designed solely with a view to peace-time application.

This represents a most important advance in the post-war use of radar, for although many ships have been fitted, as an interim measure, with sets converted for peace-time marine use from certain types of naval radar, these converted sets do not measure up to the exacting and far-sighted specifications of performance which have been laid down by the Ministry of War Transport, covering the functional requirements of ship-borne radar navigational equipment for Merchant Navy service.

The set on the "Port Pirie" was produced by Metropolitan Vickers Electrical Co., Ltd., in close association with Siemens Brothers and Co., Ltd., and is a virtually complete vindication of radar as a navigational aid in civil vessels.

TECHNICAL DETAILS

The nominal frequency of the M.R.I. is 9500 mc/sec., and in practice may be adjusted to any frequency with the band 9425-9525 mc/sec., which is well inside the limits of the 3 cm. band as now specified for this purpose.

The pulse recurrence frequency is 1000 c/sec., which is obtained directly from the 1000 c/sec. motor-generator which supplies power for the whole set, and is part of the complete installation.

The pulse-width is ¼ microsecond, which assists in giving the set its excellent minimum range figure of 40 yards.

The aerial consists of a wave-guide fed cylindrical paraboloid or "cheese," giving a horizontal beam width of ±1 degree at the half power points, and a total of 40 degrees in the vertical plane. As would be expected from the extremely narrow beam and short pulse duration, the discrimination of the set for objects in the horizontal plane is very great indeed.

The performance of the set in this respect can be gauged from the very fine picture on our front cover this month, which was taken directly from the P.P.I. of the "Port Pirie's" set as she lay at Glasgow Wharf in Wellington.

The set is arranged in two main portions, one of which, the operating console, is located in the ship's chart-room, so that the display is at hand at all times for the navigating officer should he require it. There is provision, too, for a remote P.P.I. which would normally be situated on the bridge.

The aerial, transmitter, and "front end" of the receiver, together with the automatic T.R. switching equipment, are located on the top deck, above the bridge, which places the aerial at its optimum height of 60 feet above the surface of the sea.

The receiver local oscillator frequency is automatically controlled so that no receiver tuning adjustments are necessary at the operating position in the chart room, and losses are minimised by placing the receiver mixer and oscillator in the same compartment as the transmitter, the signal being fed to the main unit below at the Intermediate Frequency. Thus, the operating console contains only power supplies, switching equipment, pulse circuitry and display unit, and the main I.F. and video amplifier stages.

OPERATION

Very notable advances discernible in this set are the simplicity of operation which has been achieved, and the manner in which the accuracy of range and bearing indications is maintained, irrespective of the way in which the controls are manipulated. It is almost impossible if the set gives an answer at all for that answer to be a wrong one.

When it is realised that the set is used mostly by non-skilled personnel—non-skilled, that is, in radar technique—this last is of vital importance. No more fitting tribute to the design and construction of the apparatus could be paid than the fact that the ship's officers, during a short voyage, and with no detailed knowledge of radar, speak most highly of the set's usefulness in all situations where radar could be expected to be effective as an aid to navigation.

Rola "Anistropic" speakers are guaranteed for 12 months from date of manufacture.

FREQUENCY MEASUREMENT

(Continued from p. 32.)

700 and 1400 kc/sec., and for signals at 875 and 1225 kc/sec., the only practical limitation being the difficulty of detecting the higher harmonics.

AMBIGUITIES DUE TO IMAGES

In an earlier instalment of this series, the question of ambiguities due to image responses was considered in some detail. With the measurements just described, the ambiguities are limited entirely to the signals from the standard, and the images, if they occur, can be discounted by the procedure given. However, no image ambiguities are introduced so long as the proper 100 kc/sec. calibration points have been found on the receiver dial. Even so, the cases that have been considered in this instalment are not likely to be troubled by image responses unless a very poor broadcast receiver is used. A T.R.F., or a superhet. with one stage of R.F. amplification, should eliminate all possibility of trouble in this respect.

(To be continued.)

"RADIO and ELECTRONICS"

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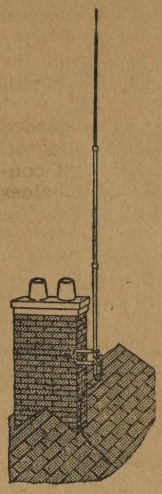

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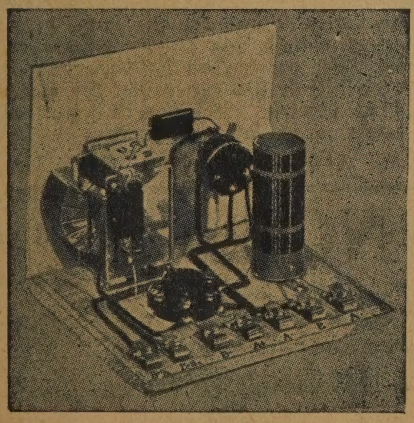

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HIGH-GAIN PRE-AMPLIFIER

(Continued from page 11.)

to cause trouble in tuning the receiver. The latter may be tuned independently over a fairly wide range, particularly on the shortwave bands, and after a station has been tuned in, the best results can be obtained by then retuning the pre-selector for maximum signal.

The gain is very appreciable even at 20 mc/sec., and so is the improvement in signal-to-noise ratio when it is used with any ordinary set which does not incorporate circuit refinements such as the infinite impedance mixer or a low-noise R.F. stage. The pre-selector was tested in front of the Radel Dual-wave Six, and it was found that signals which were barely operating the receiver's A.V.C. almost closed the magic eye when the pre-selector was brought into tune.

TRADE WINDS (Continued from page 19.)

WESTONHOUSE RADIO MOVE

Westonhouse Radio, Ltd., of Auckland, have recently moved from Rutland Street to newer and bigger premises in Sharlands' Building in Kitchener Street. The larger accommodation should be very advantageous to this rapidly-expanding firm.

VERY HIGH QUALITY AMPLIFIER

(Continued from page 39.)

complete confidence in the knowledge that any limitations in performance are not due to the amplifier itself. It is hoped at a later date to publish complete performance data, including response and distortion curves, as it is felt that these will be of considerable interest to readers.

ELECTRONICS IN METEOROLOGY

(Continued from page 7.)

oscillator, and when the signals correspond (indicated by earphones and also a cathode-ray oscilloscope), a reading of the beat oscillator is made. During the early stages of a flight, the meteorological elements are switched into circuit at intervals of about six seconds, and so the operator must perform the necessary tuning of the beat oscillator within this period.

In the next article of this series, a description will be given of some variable radio frequency types of radiosondes, of which the Finnish, German, and Japanese radiosondes are examples.

PRACTICAL TROUBLE SHOOTING

(Continued from page 28.)

amplifier is usually fitted with an R.F. bypass condenser to chassis of values varying from .0001 to .0005 mfd., though .00025 mfd. is a common figure. Therefore, if substitution of new components in the filter has no beneficial effect try substitution of the anode bypass condenser of perhaps a slightly higher value.

Finally, see that all screened leads are adequately earthed, preferably at both ends and at a few intermediate points as well, depending on the length of the lead. Unless properly earthed, screened leads can be a positive menace in introducing unwanted coupling. Heater wiring may also introduce instability, especially in newly-constructed sets. The remedy is to connect 0.1 mfd. bypass condensers to earth from each of the heater pins of a suspected valve, if rearrangement of the wiring layout cannot be conveniently carried out.

Next month this discussion will be continued with a consideration of the various forms and causes of distortion.

(To be continued.)

PRACTICAL BEGINNERS' COURSE

(Continued from p. 36.)

and three in series give 4.5 volts. However, this need not worry us unduly, for the valves which have 2-volt filaments will work quite well as detector diodes with only 1.5 volts on the filament. Next, the modern valves with 1.4 volt filaments are intended to be run off a 1.5v. cell, which only gives this slightly high voltage when quite new. As for the 4-volt valves, no harm will come from running them off 3 volts for this purpose, as this will give them plenty of emission. If desired, the 4-volt valves may be run from three 1½v. cells in series, or from a 4½v. battery without harming them.

For long battery life, the best way to make up the required voltage is to use one, two, or three No. 6 cells in series. These are the large ones sold for running electric bells and similar apparatus, and will give very long service on light-current drains. If these are too big or too expensive, the small No. 9 cells used in electric torches will give quite a number of hours of useful service.

(To be continued.)

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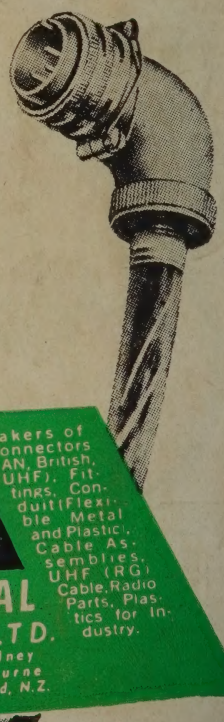

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